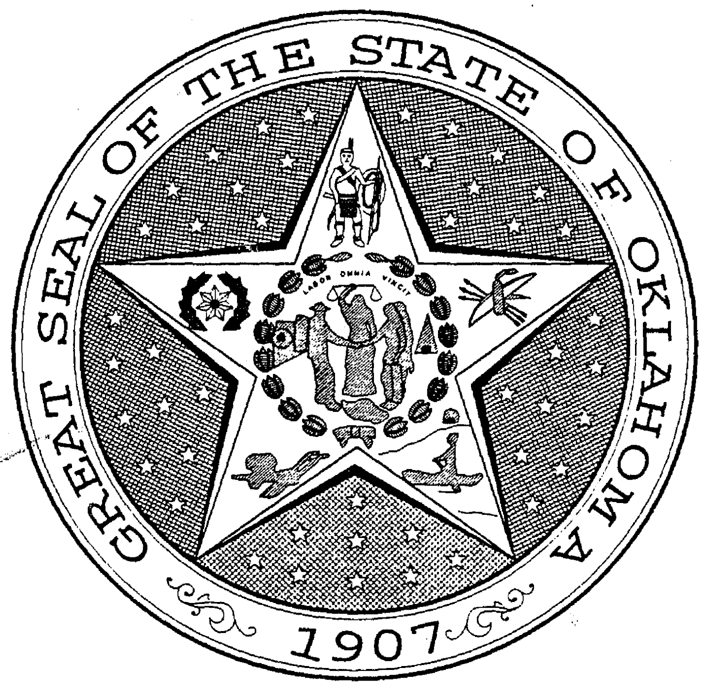
DIAGNOSTIC AND FEASIBILITY STUDY of GRAND LAKE O' THE CHEROKEES

PHASE I OF A CLEAN LAKES PROJECT

Final Report



Prepared By:

Oklahoma Water Resources Board
Water Quality Programs Division
Post Office Box 150
Oklahoma City, Oklahoma 73101-0150

Oklahoma State University
Water Quality Research Lab
426 Life Science West
Stillwater, Oklahoma 74078-0459

10 March 1995

Abstract

Title of Study: DIAGNOSTIC-FEASIBILITY STUDY OF WATER QUALITY IN GRAND LAKE, OKLAHOMA

Scope and Method of Study: A Phase 1 Diagnostic-Feasibility study was initiated to determine the temporal and spatial distribution of levels of metals and nutrients in the water column and metals in the sediment of Grand Lake. The spatial and temporal distribution of nutrients were determined by analysis of nitrogen and phosphorus in samples collected monthly from sampling stations along a gradient from the upper to lower end of the reservior. The trophic status of the reservior was evaluated by a combination of assessing the annual loading of phosphorus and nitrogen versus mean retention time of water and mean annual concentration of phosphorus, nitrogen, Secchi disk, and chlorophyll *a* in the reservior.

Availability of metals to the biota was estimated by analyzing samples of water, sediment and fish tissue collected from Grand Lake. Water samples were analyzed via atomic absorption for arsenic, selenium, mercury, lead, copper, cadmium, iron and zinc, sediment for the same with the exception of arsenic and selenium and fish tissues were analyzed for cadmium, lead and zinc. Levels of metals in kidney and liver tissue were compared between fish caught from an upper and lower station on the lake. Sediment samples were collected from four stations on the lake and extracted at pH 4, 8 and 10 for use in bioassays with *Ceriodaphnia dubia*, *Daphnia magna*, *Hyallela azteca*, and *Pimephales promelas*.

Findings and Conclusions: Levels of metals were significantly higher in the sediment from the uppermost station when compared to the lowermost station. Significant differences existed in levels of zinc in kidney and liver tissue sampled from fish taken from the upper and lowermost stations. No difference in survival or reproduction of *C. dubia* during ~ 7-day test of lake column water from the four lake stations was observed. Sediment extracts produced no toxicity to *H. azteca* or *C. dubia* in a 48-hour assay. Sediment from Station 4 when extracted at pH 4 produced a mean of 83% mortality among three replicates of *D. magna*. Significant mortality in a 7-d Fathead Minnow Embryo-Larval Survival and Teratogenicity Assay was observed for sediment from Station 4 when extracted at pH 8.

The mean annual concentration of phosphorus and chlorophyll *a* measured at the upper end, Elk River, and Honey Creek arms of Grand Lake were indicative of eutrophic conditions within these sections. A gradient in trophic status was evident in the epilimnetic strata of the lake, i.e., from eutrophic at the upper end to oligotrophic at the lower end. The entire lake was affected by eutrophication at the upper end as evidenced by the presence of anoxic conditions in the hypolimnion during the summer stratification period. The principle investigators recommend that the eutrophication process be controlled or reversed by reducing phosphorus input to the lake from both point and nonpoint sources.

Acknowledgements

The principle investigators, S. L. "Bud" Burks and Jerry Wilhm, wish to publicly express their appreciation for the conscientious effort and dedication of the graduate research assistants and technicians who worked on this project. Denise Hampton (M.S. Env. Sci.), Noble Jobe (M.S. Zoology), Doug Reed (Ph.D. Sociology) and Deldi Schut (M.S. Env. Sci.) performed the bulk of the work and deserve recognition for their efforts. The technical staff of the OSU Water Quality Research Lab, Elaine Stebler, Sarah Kimball, Bob Johnson, Liza Robertson, Hildi Overcash, Garry Yates also participated in the collection of field samples, analyses of samples, data analysis, and report preparation.

The staff of the Oklahoma Water Resources Board were extremely helpful and we wish to extend our appreciation to Dave Dillon and Shawn Simpson. We wish to thank a former employee of the OWRB, Jerry Black for his assistance during the early startup stages of the project.

Johm Mott, a part-time OWRB employee, of Miami, OK was very instrumental in assisting us during the early stages of locating sampling sites and access to the lake. His knowledge of the local environment, especially the lake, saved us many hours of travel and collecting time. John also helped collect the fish for metal residue analyses.

We wish to acknowledge the cooperation of the OSU Cooperative Fisheries and Wildlife Unit staff, Dr. Al Zale, and graduate research assistants; Vince Travenichek, Ken Sorenson, Todd Adornato and Jan Mord. They provided us with additional physico-chemical data and with fish from Grand Lake.

The Grand River Dam Authority were extremely cooperative and provided copies of their data collected for application for renewal of the hydrological generating facility at Pensacola Dam. Gary Hunt of the Benham Group, Tulsa, OK, acted as liaison between us and GRDA. We wish to extend a personal note of appreciation for his considerate and prompt responses to requests for data.

Land use data and maps for Craig, Delaware, Ottawa, and Mayes Counties in Oklahoma were provided by Ron Treat and Darrel Hammond of the USDA Soil

Conservation Service office in Stillwater, OK. Land use data for southwestern counties in Missouri was provided by the Missouri Dept. of Natural Resources.

EXECUTIVE SUMMARY

Introduction: Grand Lake of the Cherokees is located in northeastern Oklahoma (Ottawa and Delaware Counties) and was formed by the Grand River Dam Authority (GRDA) in 1940 through the construction of Pensacola Dam on the Grand Neosho River. Grand Lake is Oklahoma's most popular tourist and recreation spot. It is the third largest reservoir in the state in both capacity and surface area. At normal pool elevation, Grand Lake has a mean depth of 36 feet, a maximum depth of 164 feet, covers 46,500 acres and holds 1,672,000 acre-feet of water.

The drainage basin above the dam includes the Grand Neosho River, Spring River and Elk River. The Spring confluences with the Neosho River just above Grand Lake. The combined rivers are called Grand River downstream of the lake. The total drainage area of Grand Lake is 10,298 square miles (Figure 1).

Historically, Grand Lake's fishery and water quality have been excellent. The fishery has been one of the best in Oklahoma with an average unadjusted fish crop of 445 pounds per acre since 1949. However, in the past decade, contamination of the Neosho and Spring rivers with acidic waters seeping from abandoned lead and zinc mines has greatly increased the potential for deterioration of water quality. Another potential water quality problem in Grand Lake has been the development of algal blooms and other indications of enrichment in the Honey Creek and Elk River arms and occasionally other arms of the lake. Knowledge of and concern over these potential problems led the Oklahoma Water Resources Board (OWRB) to prepare and submit an application for grant money, to conduct a Phase I Lake Study, to the U.S. Environmental Protection Agency (EPA). The application was approved and the OWRB contracted much of the technical work associated with the study to Oklahoma State University. A plan of work was developed and the study initiated in the spring of 1987.

The Phase I diagnostic/feasibility study of Grand Lake, which was conducted primarily from the Spring of 1989 through the Fall of 1990 was made possible through a $100,000.00 Clean Lakes Assistance Grant from the EPA. This study is part of an ongoing, federally-funded effort designed to restore the recreational uses of

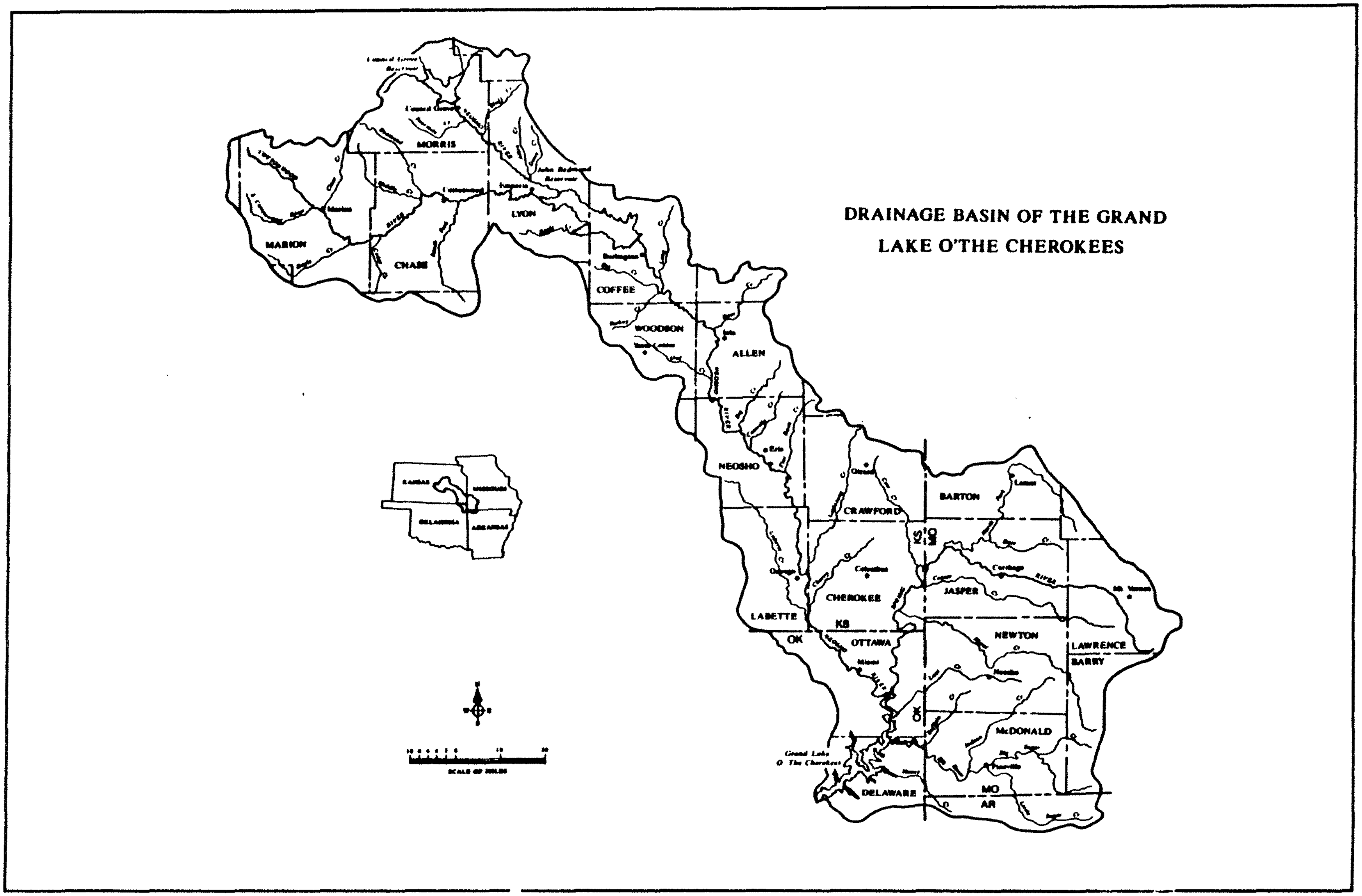


Figure 1. Grand Lake drainage basin (OWRB).

lakes and reservoirs in the United States. The state of Oklahoma has been a participant in this effort since the late 1970's.

The basic objective of any Phase I study is to determine the presence and/or extent of any water quality problems, evaluate possible solutions, and ultimately to recommend a feasible program designed to solve identified problems and thus preserve and/or restore the quality of a lake for recreational use.

The specific objectives investigated included a determination of the following in Grand Lake:

1. nature and extent of nutrient problems,
2. nature and extent of toxicity,
3. potential solutions to nutrient and toxicity problems, and
4. recommended programs to preserve or restore the quality of water.

As previously stated, much of the field work for this was conducted by personnel from Oklahoma State University and the OWRB during 1989 and 1990. Resources for the study effort were divided and emphasis was placed on in-lake evaluations of potential toxicity resulting from sediment metals accumulation and the degree of potential nutrient problems in the lake. Because resources were heavily expended to determine if sediment metal concentrations in upper Grand Lake posed a threat to the lake as a whole, it was not possible to obtain sufficient data to characterize Grand Lake by this study alone. Fortunately, other sources of data and information representing an expanded historical perspective were available and were obtained for this study. Specifically, data collected by the Grand River Dam Authority (GRDA) for the period from May, 1987 through October, 1990, was used extensively in the study. Trend monitoring data of the United States Geological Survey (USGS), which for some stations is available from the mid-1970's through the late 1980's, was used to evaluate increasing or decreasing nutrient concentration trends in selected tributaries of Grand Lake over time.

A total of eight in-lake sampling stations were used for this study in addition to the nine USGS tributary stations from which historical water quality data was obtained. The eight in-lake stations were scattered throughout the length of the lake as illustrated in Figure 2. Four of the stations were established in the main body of Grand Lake (stations 1-4) while four (stations 5-8) were established by the GRDA in major arms (Figure 2).

Traditional limnological methods of data collection and analysis as well as specialized toxicity testing and fish tissue analyses were used during this study. Both the methods of collection and of analysis are described in detail in the main body of the Phase I report.

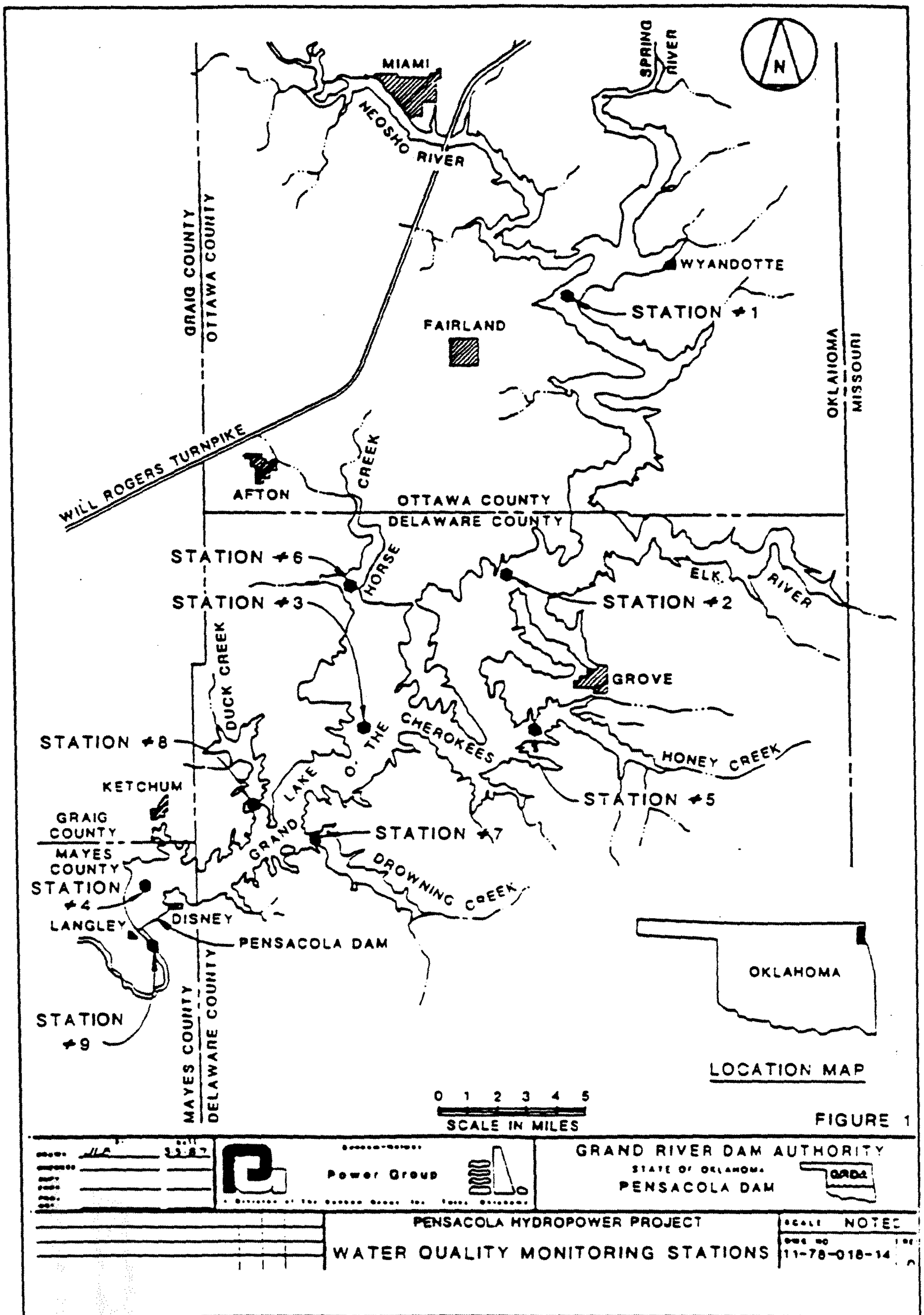


Figure 2 Grand Lake with sampling stations (GRDA).

Findings and Conclusions.

Potential metals contamination in the upper end of Grand Lake has been a concern since the early 1980's. In 1983, the Environmental Effects Subcommittee of the Tar Creek Task Force released a report prepared by the U.S. Fish and Wildlife Service National Reservoir Research Program, "*Effects of Acid Mine Drainage from Tar Creek on Fishes and Benthic Macroinvertebrates in Grand Lake, Oklahoma*". Conclusions from that work specific to Grand Lake indicated that species composition and standing crops of fish showed no effects of heavy metal contamination. Furthermore, the report concluded that heavy metals would continue to be accumulated in sediments although the accumulation was not judged to be dangerous to the aquatic community of Grand Lake at the time the report was written. The report also recommended periodic monitoring to evaluate long-term biological effects of metal contamination.

Findings of the current metals evaluation tent to support the earlier conclusion in that there were no significant toxic effects upon sensitive species of small fish or micro-crustaceans exposed to water samples collected from various regions of the lake. The levels of lead and zinc were significantly higher in sediment from the upper end than from the downstream portion of Grand Lake. However, the metals appear to be chemically bound to the sediments since toxic levels of metals could not be extracted from lake sediments at ranges of pH that exist in the lake, i.e., from minimum of 6.8 to maximum of 8.8. Toxic levels of zinc could be extracted from sediments at upper end of the lake at pH's of 6 or less as demonstrated through laboratory experiments, but the pH of the lake should not drop below 6 under normal circumstances.

The upstream portion of Grand Lake is impacted by heavy metal contamination from the abandoned lead-zinc mines; however, the contamination appears to be confined to sediments in the upper reaches of the lake and does not pose an immediate threat to the overall quality of water in Grand Lake.

Under extreme conditions, continued metals transport from upstream tributaries and/or increased eutrophication might decrease pH from the currently measured low of 6.8 units to a "critically" low pH of 6.0. Dissolution of metals from the sediment would potentially become a serious problem in Grand Lake under conditions of low pH. Again, it should be stressed that a drop in pH to 6.0 units, which would probably result in toxic releases of zinc, is not a likely occurrence.

Data collected from upstream tributaries by USGS were analyzed to determine if nutrients such as nitrogen and phosphorus were increasing, decreasing, or remaining the same over time. The findings from this evaluation were somewhat mixed. Overall, the results of the trend tests on the Neosho River indicate that total phosphorus levels have been increasing over time. This is evident at USGS 07183500 at Parsons, Kansas and at USGS 07185000 at Commerce, Oklahoma. However, the trend tests for nitrite plus nitrate levels have indicated no significant increasing trend over time for the Neosho River. For the Spring River, trend tests on both total phosphorus and nitrite plus nitrate indicate no significant upward trend in the nutrient levels over time.

The upper end of the lake and Elk River and Honey Creek arms were judged to be eutrophic (over fertilized) when the concentration of chlorophyll *a* (an algal pigment) and nutrients such as phosphorus and nitrogen were compared with Reckhow's (1988) criteria for impoundments in Florida. The remainder of the lake was not considered to be highly enriched. However, the entire lake is being influenced by eutrophication processes occurring in the upper end of the lake. The lake naturally stratifies during summer due to rapid solar heating of the upper strata. The warm upper layer cannot mix with the cool denser layer on the bottom. Organic matter imported from the rivers and also from growth of algae in the sunlit upper layers, falls into the bottom layer of the lake where it is degraded by bacteria. Bacterial degradation of these organic compounds use all of the available oxygen from the bottom layer of the lake. This produces a condition where there is no oxygen available for fish to breathe and therefore the bottom layer of the lake cannot support desirable forms of aquatic life during the summer. These anoxic conditions also affect the chemistry of phosphorus within the lake, resulting in a recirculation of phosphorus from the sediments as well as the input from external sources.

Phosphorus acts as a nutrient to stimulate growth of algae. As a result, the lake is rapidly accelerating into eutrophic conditions and decreasing water quality.

In summary, it appears that the recreational uses of Grand Lake (swimming, boating, fishing) as a whole are relatively intact. However, continued degradation of water quality due to excessive nutrients and metals could lead to serious impairments in use of the lake. Metals which are currently bound to sediments in the upper end of Grand Lake should not be disturbed. Physical disruption of the bottom sediments, such as would occur during dredging, could lead to an environmental crisis in Grand Lake through release of toxic concentrations of metals into the water column. Monitoring of water quality in Grand Lake should be continued on at least a periodic basis and remedial efforts expanded if conditions of the lake worsen over time.

RECOMMENDED REMEDIATION EFFORTS.

Heavy Metal Contamination. We recommend the efforts to prevent heavy metal contamination from the abandoned lead and zinc mines be continued. The current level of contamination appears to have caused some localized impacts in the upper end of Grand Lake. However, continued heavy metal contamination coupled with eutrophication could produce conditions which would accelerate transport of metals throughout the remainder of the lake and the Grand River basin.

Eutrophication. We recommend two voluntary programs be initiated to attempt to reduce phosphorus contamination within the basin:

1. Voluntary switch to non-phosphate detergents by all lake side residents and the cities of Grove and Miami, OK.
2. Implementation of a best management practices upstream from Grand Lake to minimize contributions of phosphorus in surface water runoff from agricultural fertilizer applications.
3. Continue to work with point source dischargers, to the extent possible within the watershed, to minimize discharges of nutrients including phosphorus.

RATIONALE.

If the concentration of phosphorus was reduced in Grand Lake, how would this affect water quality?

Reckhow (1988) used data from 80 lakes and reservoirs in the southeastern United States to develop a generalized equation relating concentration of phosphorus and nitrogen to production of algae as measured by chlorophyll *a* concentration. We used Reckhow's general equations to calculate similar relationships for Grand Lake and as a tool for predicting future algal density if phosphorus was reduced.

The growth of algae is generally increased by an increased level of phosphorus in the water. In fact, high concentrations of phosphorus often leads to extensive growth of blue-green algae, an undesirable, odor-producing form of algae. Extensive growths of blue-green algae do not presently exist in Grand Lake and our recommendations include taking measures to prevent development of nuisance blue-green algal blooms.

The measurement of chlorophyll *a*, a green pigment found in the algae, provides an index of the density of algae. Low concentrations of chlorophyll *a* indicate a low density of algae and vice versa. Since the growth of algae is increased by phosphorus, we predict a reduction in phosphorus would reduce the density of algae and chlorophyll *a* (Figure 3).

One of the problems associated with algal growths is a reduction in the clarity of the water. Thus, the aesthetic quality of the water is decreased and the lake is no longer as attractive to visitors and residents. Many of the more popular recreational lakes in the northcentral United States have low concentrations of phosphorus and therefore low density of algae. In contrast, some enriched lakes are extremely green and are not as attractive for some recreational activities. Grand Lake is intermediate to these extremes and our recommendations include implementation of measures that would prevent further deterioration in water quality.

The clarity of water is easily measured by lowering a circular disk into the water and recording the depth at which the disk disappears from view. The disk is

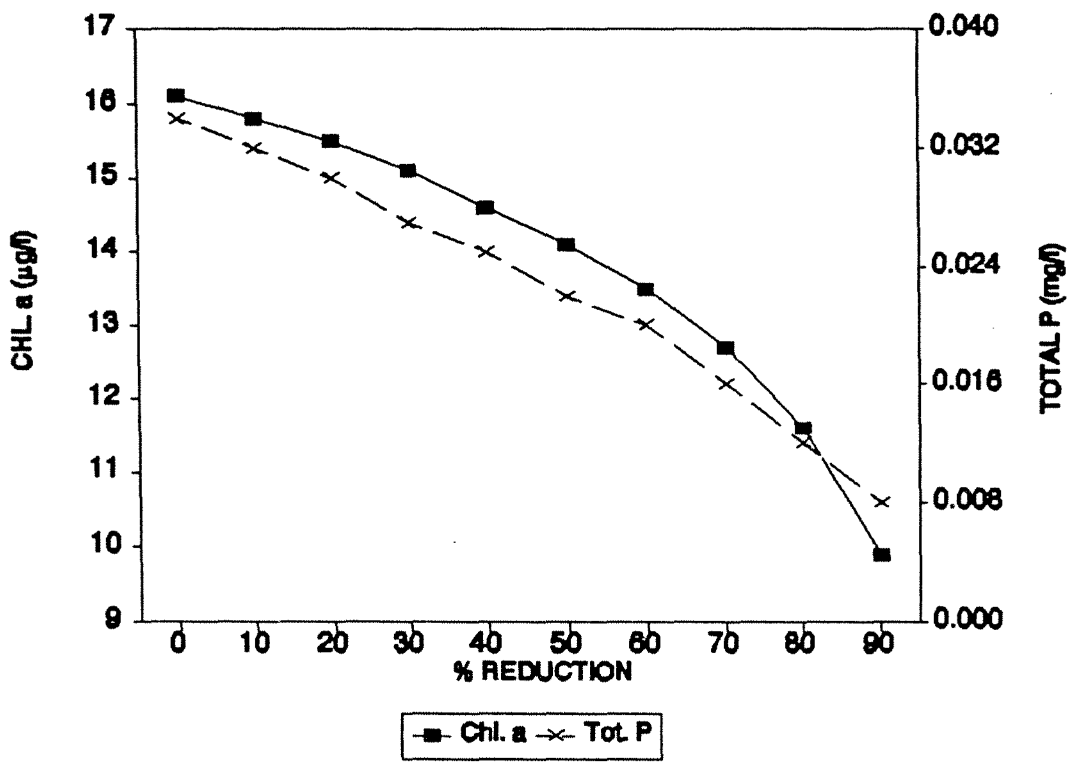


Figure 3. Predicted annual average concentration of chlorophyll *a* in response to reductions of phosphorus.

called a Secchi disk after the limnologist who developed the method. In two lakes in Michigan in summer, Secchi disk depths were generally less than 1.5 meters (about 5 feet) in an enriched lake and generally exceeded 5 meters (over 16 feet) in a nonenriched, hardwater lake.

We predict the annual average Secchi disk depth at the lower end of Grand Lake would increase in response to a reduction in overall concentration of phosphorus (Figure 4).

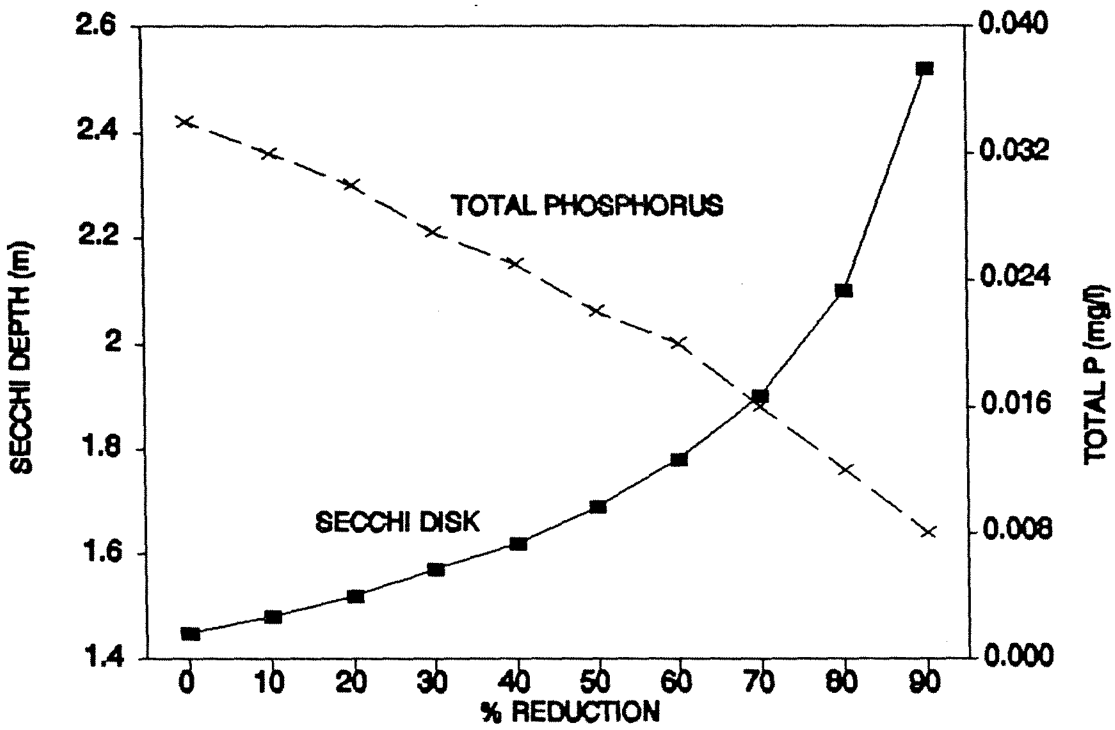


Figure 4. Predicted annual average Secchi disk depth in response to reductions in overall concentration of phosphorus.

Table of Contents

List of Tables

List of Figures

Proposal

Summary of Output Tasks for Diagnostic/Feasibility Study

Diagnostic Study Tasks	Scheduled Output Date
1. Workplan	30 JUNE 91
2. Lake Identification	30 JUNE 91
3. Geology and Soil Types	30 JUNE 91
4. Public Access	30 JUNE 91
5. Adjacent Population	30 JUNE 91
6. Historical Lake Uses	30 JUNE 91
7. Population Affected	30 JUNE 91
8. Comparative Lake Use	30 JUNE 91
9. Point Source Pollution	30 JUNE 91
10. Land Use	30 JUNE 91
11. Limnological Data	30 JUNE 91
12. Biological Resources	30 JUNE 91

Feasibility Study Tasks	Anticipated Schedule
13. Alternatives	30 JUNE 91
14. Benefits	30 JUNE 91
15. Monitoring Program	30 JUNE 91
16. Milestone Work Schedule	30 JUNE 91
17. Non-Federal Funding	30 JUNE 91
18. Relationship to Other Programs	30 JUNE 91
19. Public Participation	30 SEPT 91
20. State Operation	30 SEPT 91
21. Permits	31 JULY 91
22. Environmental Evaluation	30 SEPT 91

SCHEDULED TASKS

DIAGNOSTIC STUDY

TASK 1: Workplan

OBJECTIVE: To develop a work plan for the Phase 1 Clean Lakes Diagnostic/Feasibility Study.

DISCUSSION: A detailed workplan will be developed to coordinate activities and tasks of the participants. The primary objective will be to identify tasks which will ascertain water quality problems in Grand Lake and recommend a feasible program to restore and preserve the quality of the lake. In addition, input from Grand Lake Resort Owners Association and citizen groups will be obtained, to provide insight on the public's perception of problems in Grand Lake.

TASK 2: Lake Identification

OBJECTIVE: To identify the lake to be restored including the location within the state, the general hydrologic relationship to associated upstream and downstream waters and the approved state water quality standards for the lake.

TASK 3: Geology and Soil Types of Drainage Basin

OBJECTIVE: To describe the geology of the drainage basin including soil types and soil loss to tributaries.

DISCUSSION: The parent materials of the soils of this area are recent alluvium, old alluvium, shales, and limestone outcrops. Detailed geological studies of the area north of Grand Lake have been performed in conjunction with the Tar Creek project.

TASK 3A: Literature Survey of Geology & Soil Types

Method: Conduct a survey of geological and soil composition of the published literature and agency reports for the Neosho, Spring, and Elk River basins upstream from Grand Lake.

SUBTASK 3B: Field Survey of Neosho & Spring Rivers During Storms

METHOD: A timed series of water samples will be collected from Neosho & Spring rivers following a major runoff. Samples will be collected in polyethylene bottles and analyzed for filterable and nonfilterable trace metals by methods described in Subtask 9b.

TASK 4: Public Access

OBJECTIVE: To describe the public access to the lake including the amount and type of public transportation to the access points.

DISCUSSION: Grand Lake is located near the Will Rogers Turnpike, part of Interstate Highway 44. The lake is also accessible via Oklahoma State highways' 10, 59, 25, & 60. The lake has several public boat launch ramps and several commercial boat marinas. Development of permanent and weekend type residences along the shoreline has also lead to development of numerous secondary access roads.

TASK 5: Adjacent Population

OBJECTIVE: Description of adjacent population centers to assess potential increase in use of recreational opportunities, if lake was cleaned up.

DISCUSSION: Grand Lake is located within 70 miles of Tulsa, Bartlesville, Claremore, and Miami, Oklahoma. It is within 150 miles of Wichita, Kansas and Springfield, Missouri. Numerous weekend visitors come to the lake from these contiguous metropolitan districts. In addition, Grand Lake has several highly developed resort facilities, including Shangri La, a nationally renown privately-owned resort. The shoreline has been extensively developed for both weekend cabins and permanent residential areas. The economic benefits of recreational activities associated with Grand Lake are already considerable, and could be even greater if water quality can be improved.

TASK 6: Historical Lake Use

OBJECTIVE: Statistical summary of historical use of the lake and how this use may have changed due to changes in aesthetics and water quality.

DISCUSSION: Grand Lake was formed in 1940 by damming the Grand River. Project purposes are hydroelectric power generation, flood control, and recreation. Grand Lake has provided residents of Oklahoma and surrounding states excellent fishing, boating, and picnicking activities for many years. Hopefully, water quality can be maintained or improved in order to enhance these recreational opportunities for many more years.

TASK 7: Population Affected by Lake Degradation

OBJECTIVE: Assessment of the particular segment of the population which would be adversely impacted by further degradation in water quality of Grand Lake.

TASK 8: Comparative Lake Use

OBJECTIVE: Comparison of the beneficial uses of Grand Lake with other lakes within a 80 kilometer radius.

DISCUSSION: A comparison of recreational and other beneficial uses of lakes within an 80 kilometer radius of Grand Lake will be made by consulting with Oklahoma Department of Tourism, Oklahoma Department of Wildlife Conservation, and the Oklahoma Water Resources Board.

TASK 9: Point Source Pollution

OBJECTIVE: To inventory known point source pollution discharges affecting or which have affected lake water quality over the past 5 years and abatement actions for these discharges.

DISCUSSION: Information regarding point source contribution to the Grand Lake Watershed was sparse, however design criteria for basin point source dischargers are provided in Appendix B. Of primary concern with regard to water quality in Grand Lake is the development in close proximity to the Lake itself. This extensive development of residential cabins and homes on Grand Lake shoreline may be contributing considerable quantities of nutrients to the lake, due to the practice of using septic tanks for domestic waste disposal.

In addition, several sources of acidic mine wastes exist in both the Neosho and Spring river watersheds. An extensive study has been performed on the quantity of acidic mine waters and associated heavy metal contaminants from Tar Creek, a tributary to Neosho River. Until the recently completed EPA Superfund Diagnostic-Feasibility study of the Galena subsite in Kansas, there had been no evaluations of the quantities of heavy metal contaminants in the Spring River watershed, although several investigators have indicated relative significant contamination.

SUBTASK 9a: Inventory of Point Source Pollution

OBJECTIVE: To determine the number and quantity of inputs from Point Sources.

DISCUSSION: We obtained a listing of point source dischargers in the Neosho, Spring, and Elk River basins above Grand Lake. The EPA Storet System was accessed to obtain a list of all NPDES permittee's for the basin. Unfortunately, the computer data base did not contain actual flow and concentration data, however it did contain treatment plant design criteria (Appendix B). .

SUBTASK 9b: Field Survey of Neosho and Spring Rivers During Normal Flow

OBJECTIVE: To determine the current water quality in Neosho and Spring Rivers during normal flow.

DISCUSSION: We conducted a field survey of the Neosho and Spring Rivers during the initial stages of the project to determine if quality of the water was atypical during normal flow. In addition to our field survey, we obtained records from the USGS water quality gaging stations on Neosho and Spring Rivers (See Subtask 11a).

TASK 10: Land Use

OBJECTIVE: To describe land use practices in the lake watershed as a percentage of the whole and discussion of the amount of nonpoint pollutant loading produced by each category.

DISCUSSION: The watershed above Grand Lake is primarily used for cattle grazing, hay production, and some intensive agricultural practices. Extensive mining operations and disposal of wastes from the mines in surface chat piles may be contributing some trace metal contamination to the surface water runoff.

TASK 11: Limnological Data

OBJECTIVE: To compile and analyze the historical baseline limnological data and to measure 1 year of current limnological data.

DISCUSSION: Grand Lake is a valuable resource for the State of Oklahoma. In addition to the hydroelectric power generation, flood control, and water supply, it also provides a valuable recreational resource for Oklahomans and residents from Kansas, Missouri, and Arkansas.

The major problems existing in Grand Lake include contamination by heavy metals from lead/zinc mining wastes and nutrient enrichment. The heavy metal contamination results from flooding of abandoned lead/zinc mines and subsequent contamination of surface streams. The nutrient enrichment results from anthropogenic inputs from extensive development along shoreline and use of septic fields in a highly fractured limestone and from upstream municipal public owned treatment systems.

SUBTASK 11a: Historical Baseline Limnological Data

METHOD: Several projects have been conducted in the past 5 years in conjunction with the Tar Creek investigation of acid mine waste contamination of surface waters. These reports will provide a baseline for estimating the heavy metal contamination. In addition, surveys were conducted of general limnological parameters in Grand Lake prior to the Tar Creek project.

The EPA national eutrophication survey included Grand Lake as one of the lakes sampled in Oklahoma. In addition, one M.S. thesis project has been performed on metal contamination upon upper end of Grand Lake (McCormick, 1985).

As part of the requirements for renewal of the Federal Energy Regulatory Commission permit for hydroelectric generation, the GRDA is currently conducting a survey of general limnological parameters in Grand Lake. We propose to compliment the on-going GRDA study by focusing on other parameters.

SUBTASK 11b: Morphometry

METHOD: The following parameters will be determined from existing data on Grand Lake: length (l), width (w), shore line length (L), shoreline development (D_L), and drainage area. Maximum depth will be determined with a sonar depth finder. GRDA has planned a detailed morphometric study as part of their FERC permit application and therefore will not be included as part of the tasks under the "Clean Lakes Project".

SUBTASK 11c: Hydraulic Budget

METHOD: Data Analyses of the following:

Lake levels and precipitation records from GRDA and U. S. Weather Bureau
Discharge and hydroelectric generation records from GRDA
Total usage of municipal water from local city records
Pan evaporation estimated from general records

SUBTASK 11d: Physicochemical Conditions of the Water

METHOD: Measurements will be made from four sites distributed along the length of Grand Lake to obtain an index of change in nutrients and trace metals from the upper to the lower reaches of the lake. It is anticipated that the greatest change in concentration occurs in the upper end of the lake as suspended materials transporting adsorbed trace metals sediment in the quiescent lake waters. Therefore, we propose to collect additional samples more frequently in the upper end of the lake. Samples will be collected seasonally.

The variables listed for the field survey of Neosho and Spring rivers during normal flow conditions (Subtasks 9b and 11a) will be measured by the methods described.

SUBTASK 11e: Sediment Analysis

METHOD: Sediment samples will be collected for subsequent laboratory analysis of bioavailable trace metals, since previous studies have indicated a potential contamination problem (McCormick, 1985). The sediment samples will be extracted with reconstituted water used to culture fathead minnows, *Daphnia magna*, and *Ceriodaphnia dubii*. The pH of the reconstituted water will be adjusted to simulate potential worst case conditions prior to the extractions. The extraction elutriates will then be readjusted back to neutral pH and evaluated with short-term chronic assays to determine if deleterious levels of substances are bioavailable from the sediments.

Sediment elutriates will be assayed with short-term fathead minnow embryo-larval teratogenecity, *Ceriodaphnia* and/or *Daphnia* survival/reproduction, and the *Selenastrum capricornutum* algal test. The objective of the short-term chronic assays will be to determine the potential physical- chemical conditions which might release deleterious levels of contaminants from the sediments.

Additional bioassays will be performed on sediment samples and reconstituted water mixtures with amphipods *Hyalella azteca* to determine if there is any effect upon bottom feeding organisms.

Sediment samples will be analyzed for total digestible metal content and the sediment elutriates will also be analyzed for trace metals listed in Subtask 11a.

SUBTASK 11f: Algal Analyses

METHOD: Samples will be collected from the same stations and times as Subtask 10d, but from the epilimnion or euphotic zone only. An index of primary productivity will be obtained by analyzing samples for chlorophyll a. dominant genera of algae in the phytoplankton cell density (numbers of cells per milliliter), and cell volume.

SUBTASK 11g: Fish Flesh Analyses

METHOD: Fish representing the piscivorous, planktivorous, and detritivorous feeding groups will be collected for analysis of trace metal accumulation. The concentration of trace metals in the gall bladder will be used as an indicator of potential bioconcentration of metal contaminants.

TASK 12: Biological Resources

METHOD: Fish resources of Grand Lake will be derived from previous investigations and from on-going projects by GRDA.

Benthic macroinvertebrates will be collected with Ekman dredge hauls from the four sampling sites used for Subtask 11D and at the same time periods. The benthic organisms will be identified to lowest taxa possible.

FEASIBILITY STUDY

TASK 13: Feasible Alternatives for Lake Restoration

OBJECTIVE: To identify and discuss the alternatives considered for lake restoration and justify the selected alternatives.

DISCUSSION: Since the existing problems in Grand Lake appear to be heavy metal contamination in upper end of lake and nutrient enrichment, restoration remedies will be focused on two separate and distinct facets.

A major problem currently known to exist in Grand Lake is the input of toxic metals from the abandoned lead/zinc mines in the watershed. Apparently, most of the metal contaminants are sedimented in the upper end of the lake, since there have been no reports of elevated levels of lead or zinc in the lower reaches of the lake. Therefore, the diagnostic study will permit an evaluation of the quantities in the sediment and the extent of the contaminated sediments. Also, the effects of summer stratification upon solubilization of metals from the sediment and subsequent transport to other portions of the lake will be evaluated. It is fortuitous that Grand Lake is located in an area with extensive outcroppings of limestone and therefore is buffered by relatively high alkalinity concentration from the effects of the acid mine wastes.

Based upon our current knowledge the most likely sources of nutrient enrichment are anthropogenic wastes from shoreline septic fields and municipal wastewater treatment plants.

METHODS: Based upon the results of the diagnostic study and the compilation of results from either previous investigations or contemporary studies, we will develop several alternative proposals for restoration of water quality in Grand Lake. The potential impacts of each alternative upon aesthetics, water quality, ecosystem integrity, recreation, hydroelectric generation, water supply, and economics of the region will be evaluated.

TASK 14: Benefits of Restoration

OBJECTIVE: To discuss potential benefits accruing from implementation of the restoration projects.

DISCUSSION: Improved water quality should enhance recreational use of Grand Lake. Also, enhanced water quality would provide greater potential for additional beneficial uses of the lake.

METHOD: Evaluation of data from TASK 6 and input from the Grand Lake Resort Owners Association, GRDA, and city-county-state agencies.

TASK 15: Phase 2 Monitoring Program

OBJECTIVE: To design a Phase 2 Monitoring Program

DISCUSSION: A monitoring program will developed to assess the improvements in water quality of any restorative measures implemented. Also the monitoring program will record any temporary adverse effects upon water quality.

METHOD: Federal Register 45(25):798-799 (Phase 2 Procedures)

TASK 16: Milestone Work Schedule

OBJECTIVE: To provide a proposed milestone work schedule for completing the project with a proposed budget and payment schedule.

METHOD: Based upon the best alternative selected in OUTPUT 13, the proposed schedule will be developed for construction or renovation- remediation projects.

TASK 17: Non-Federal Funding

OBJECTIVE: To propose sources for obtaining nonfederal funding for required matching costs of restoration.

METHOD: Consultation with administrators of GRDA, Grand Lake Resort Owners Association, and appropriate legislators from the Grand Lake area.

TASK 18: Project Relationship to Other Pollution Control Programs

OBJECTIVE: To describe the relationship of the proposed project to other pollution control programs.

METHOD: Compatibility of proposed restoration program to other state/federal agency pollution control programs.

TASK 19: Public Participation

OBJECTIVE: Establish public participation in developing and assessing the proposed project.

METHOD: A synopsis of public response and participation in the assessment of the proposed project. In compliance with Part 25 of Federal Register 45(25), shall include the subjects presented to the public, the actions taken by the reporting agency to fulfill its obligations under Part 25, and related provisions; the public response; and the agency's response to significant comments.

TASK 20: State Operation and Maintenance Plan

OBJECTIVE: Description of State Operation and Maintenance plans to implement restoration project.

METHOD: Describe the State's Operation and Maintenance plan for insuring that the reduction and/or prevention of contamination controls are continued after the project is completed.

TASK 21: Permits

OBJECTIVE: Make application for all necessary permits.

METHOD: Ascertain and make application for all permits necessary for implementation of the restoration program, in accordance with section 404 of the Clean Water Act.

TASK 22: Environmental Evaluation

OBJECTIVE: Completion of the Environmental Evaluation

METHOD: Evaluate the potential effect of the restoration project upon the following specific areas:

1. Displacement of people.
2. Changes in established land use patterns such as increased development pressure near the lake.
3. Devaluation of existing residences or residential areas.
4. Adverse impact upon agricultural practices in the watershed.
5. Adverse impact upon parks or other public facilities.
6. Any impacts predicted by officials of the State Historical Society, State Preservation Society, or Archaeological Society.
7. Significant increase in energy consumption.
8. Air quality or noise pollution.
9. Chemical treatments' effects on upon water quality of the lake.
10. Compliance of project with EPA requirements on floodplains Order 11988).
11. Short-term or long-term impact of dredging.

12. Compliance with EPA Executive Order 11990 requirements on wetlands.
13. Evaluation of alternatives; environmental impact, commitment of resources, and public interest & costs.
14. Evaluation of other measures necessary to minimize environmental impact of restoration project.

TASK 2: Lake Identification

OBJECTIVE: To identify the lake to be restored including the location within the state, the general hydrologic relationship to associated upstream and downstream waters and the approved state water quality standards for the lake.

DISCUSSION: Grand Lake of the Cherokees is located in northeastern Oklahoma (Ottawa and Delaware Counties) and was formed by the Grand River Dam Authority (GRDA) in 1940 by constructing Pensacola Dam on the Grand Neosho River (Figure 1, Table 1). Grand Lake is Oklahoma's most popular tourist and recreation spot. It is the third largest in the state in both capacity and surface area (OWRB 1990). The dam is located at river mile 77.0 (Lat. 36° 28' 17", Long. 95° 02' 17"). The lake is located 10 miles east of Vinita and 70 miles northeast of Tulsa, Oklahoma.

The drainage basin above the dam includes the Grand Neosho River, Spring River, and Elk River (Figure 2, Table 2). The Spring River confluences with the Neosho River just above Grand Lake. The combined rivers are called Grand River below Grand Lake. The total drainage area of Grand Lake is 10,298 sq. mi.

There are two existing reservoirs on the Neosho River in Kansas. The John Redmond with 56,660 acre feet total storage capacity and Council Grove with 38,310 acre feet total storage capacity. These reservoirs provide flood control, water supply, water quality control, and recreation. In spite of these reservoirs, the total annual volume of water transported by Neosho River is 1,698,000 acre feet of water at Parsons, KN. The total storage capacity of Grand Lake at normal power pool level is 1,672,000 acre feet, therefore the Neosho River transports enough water to fill Grand Lake every year.

Grand Lake was constructed for hydropower generation, flood control, municipal and industrial water supply, fish propagation and recreational benefits.

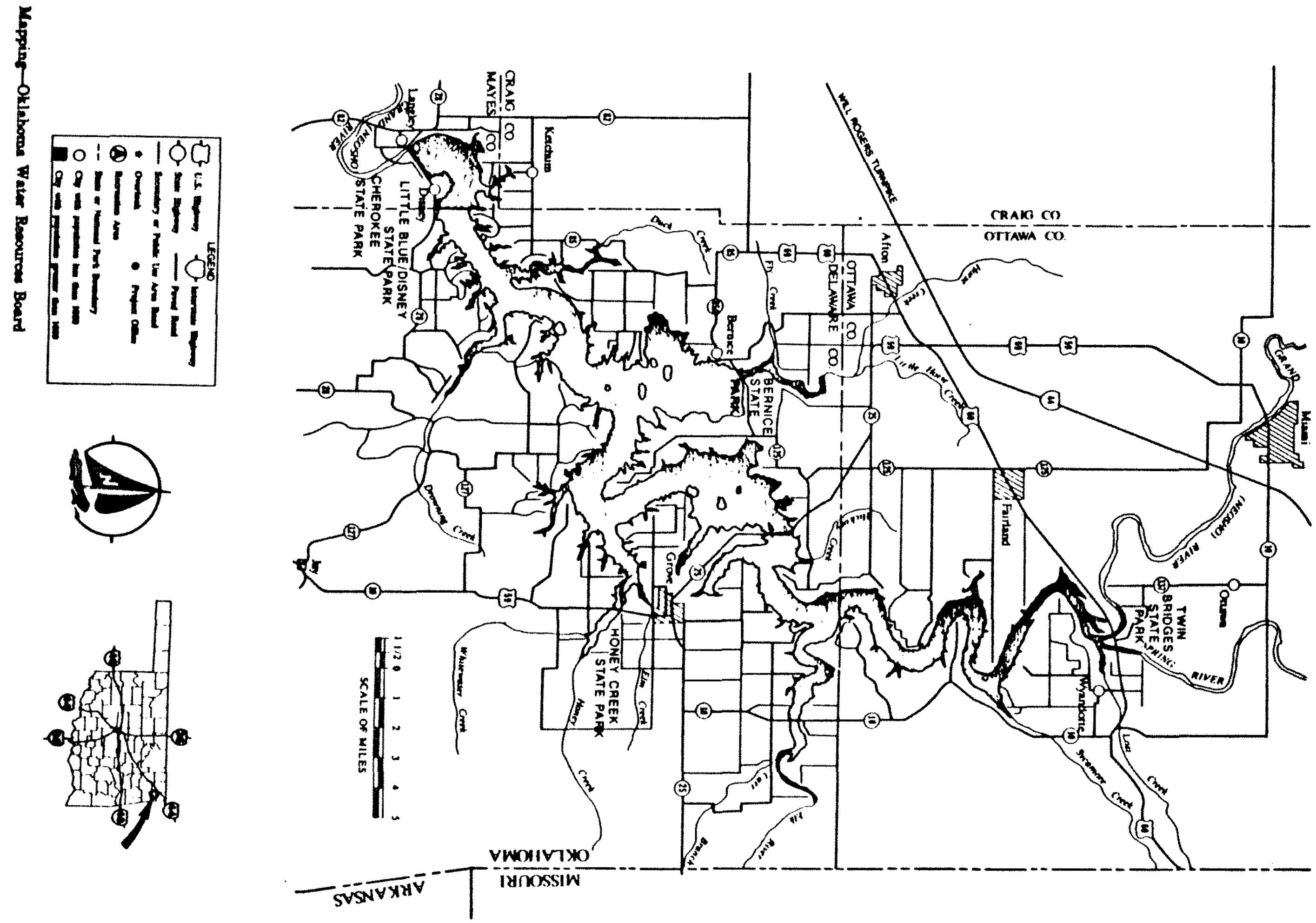


Figure 1. Map of Grand Lake of the Cherokee's illustrating access points and local communities.

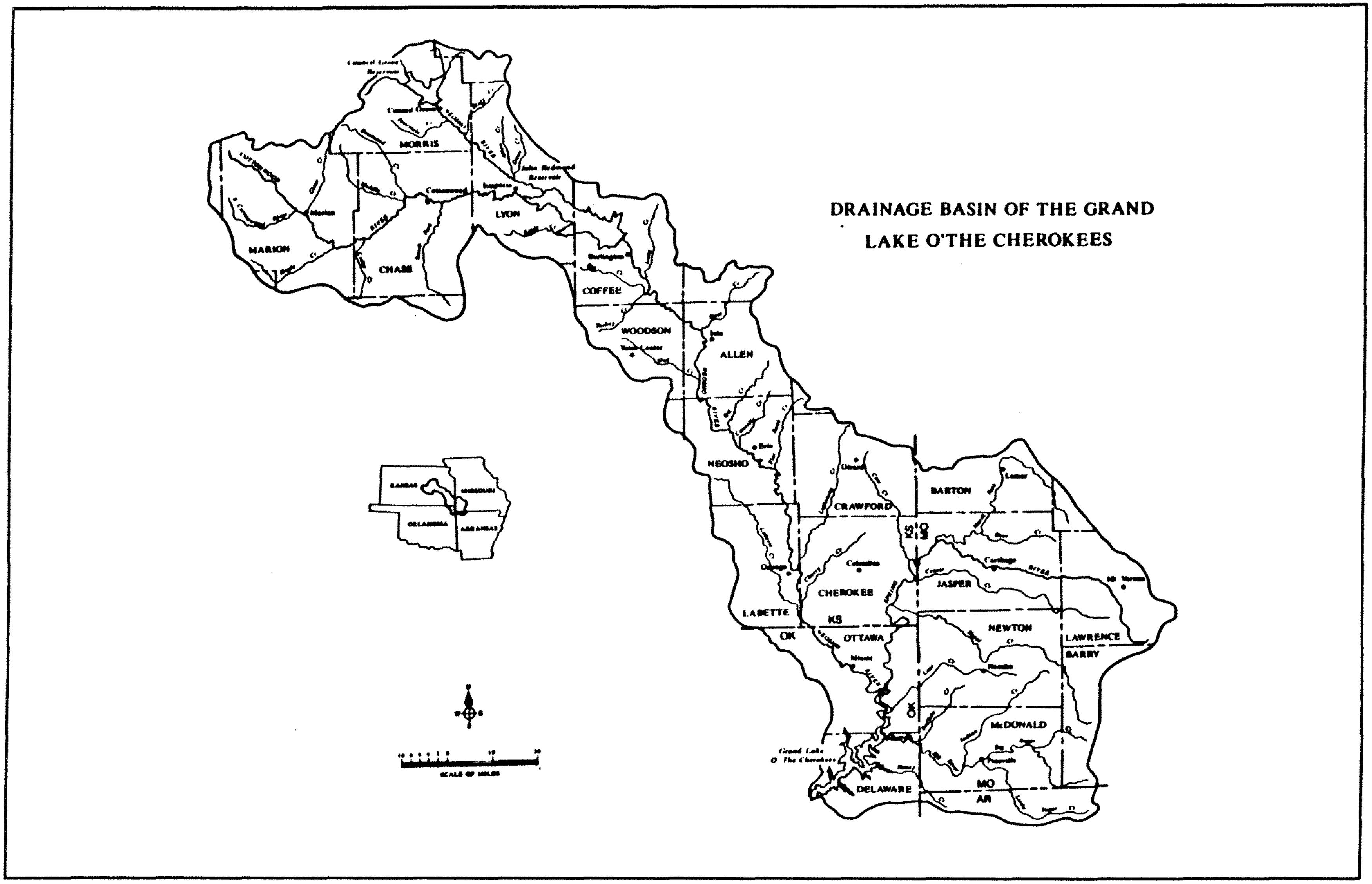


Figure 2. Drainage basin of Grand Lake.

Table 1. Major Morphological Features of Grand Lake O' the Cherokees.

Morphological Feature	Normal Pool	Flood Pool
Elevation (Ft. above MSL) (NGVD)	745	755
Area (Acres)	46500	59200
Capacity (Acre-feet)	1672000	2197000
Mean Depth (feet)	35.9	
Maximum Depth (feet)	164	
Shoreline (miles)	1300	
Shoreline development	43.1	
Volume development	0.66	

Table 2. Hydraulic Data for Grand Lake and Major Tributaries (USGS 1986).

Source	Drainage Area (mi^2)	Discharge (cfs)	Percent of Total*
Neosho River	5876	5491	50.70
Spring River	2510	3417	31.55
Elk River	872	1299	11.99
Sum of Above	9258	10207	94.24
Below Dam	10298	10830	100.00

* calculated as percent of discharge below dam

TASK 3: Geology and Soil Types of Drainage Basin

OBJECTIVE: To describe the geology of the drainage basin including soil types and soil loss to tributaries.

DISCUSSION: The parent materials of the soils of this area are recent alluvium, old alluvium, shales, and limestone outcrops. Detailed geological studies of the area north of Grand Lake have been performed in conjunction with the Tar Creek project.

SUBTASK 3A: Literature Survey of Geology & Soil Types

GEOLOGY: Grand Lake, located in Delaware, Mayes, and Ottawa counties, Oklahoma, lies above the Boone formation (also known as Keokuk-Reeds) and Roubidoux aquifers. The main axis lies on the Seneca fault (Gomez and Grinstead 1973).

The Boone formation is of early and late Mississippian periods, average depth is about 300 ft (well depths average 50 to 300 ft) with extensive fractures and solution channels. For these reasons, the Boone formation is considered very susceptible to surface contamination. The water content has been classified as moderately hard and supplies many springs in the area (OWRB 1990, USGS 1986). Most of the basin lies over the Boone formation with some Mississippian outcrops of Pitkin limestone and Fayetteville shale on the west side and North of Honey Creek arm (Gomez and Grinstead 1973). The main stream channel is late tertiary gravel. The Boone formation is comprised of weathered residual chert and clay in the upper portions and cherty limestone in the lower portions (USGS 1986). The water is hard to very hard with dissolved solids generally <500 mg/l.

Partially underlying the Boone formation is the Roubidoux aquifer, which is predominantly located in Ottawa and Delaware counties. Although many minor formations coexist with this aquifer, e.g. Cotter, Jefferson City, Gasconade, and Eminence-Potosi, the Roubidoux is the major water bearer. The water is of the $Ca(HCO_3)_2$ type. The water quality changes to that of

NaCl type towards the west. Its depth ranges from 450 to 1700 ft (OWRB 1990). Well depths average 800 to 1200 ft. Its formation occurred during the upper Cambrian and lower Ordivician periods. Associated substrates include sandstone and cherty dolomites. The percentage $Na^{+}+K^{+}$ and $Ca^{2+}+Mg^{2+}$ to total meq is 55% and 45%, respectively (USGS 1986). The anionic composition is 42% $(CO_3^{2-}+HCO_3^{-})$/total meq. and 58% $(Cl^{-}+SO_4^{2-})$/total meq. (USGS 1986). Although Cl^{-}, F^{-}, and SO_4^{2-} exceeds standards in some areas, the water quality is generally considered good (USGS 1986).

The average annual precipitation and runoff for Grand Lake is 42 and 10 inches, respectively (USGS 1986). The mean annual temperature is 58° F.

The Grand Lake drainage basin can be divided up into 3 segments, Kansas, Missouri, and Oklahoma. Less than 1% occurs in Arkansas and is considered insignificant. Hence, the previous 3 segments will be entertained.

The Kansas portion of the drainage basin comprises most of the Neosho River and some of the Spring River drainage basins. The data on the geology and soil types of this portion has been extracted from the Kansas State Water Plan Studies Part A. Section 7. The Neosho Unit (KWRB 1961). The areas of specific characteristics have been calculated using planimetry (Figure 3 and Figure 4, Table 3 and Table 4).

The surface geology in vicinity of Grand Lake is dominated by a physiographic feature named the Springfield Plateau, which is actually the western portion of the Ozark Upland. The Neosho River floodplain primarily occurs in a Prairie Plain Homocline. The Spring River and Elk River floodplains occur in the Ozark Uplands. The Prairie Plain Homocline, occurring west of the Neosho River, consists of predominantly flat plains with a slight slope to the east-southeast. The Ozark Uplands primarily occur east of the Neosho River.

Soils.

The surface soils in the prairie portion of the Neosho River basin belong to the Parsons-Dennis-Bates association (Table 4 and Table 5). These

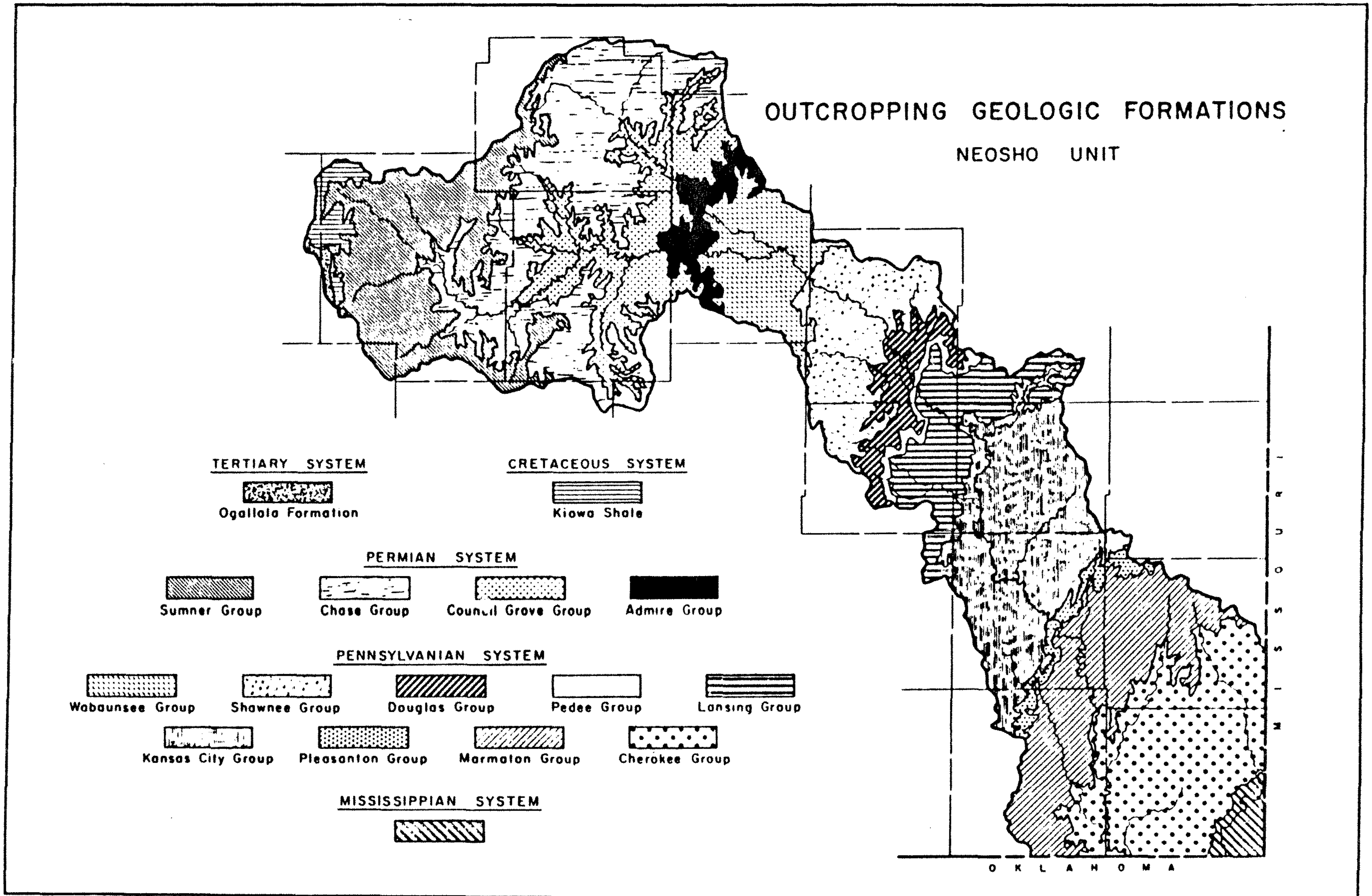


Figure 3. Outcropping geologic formations in the Neosho Unit of the Grand Lake basin in Kansas (KWRB, 1961).

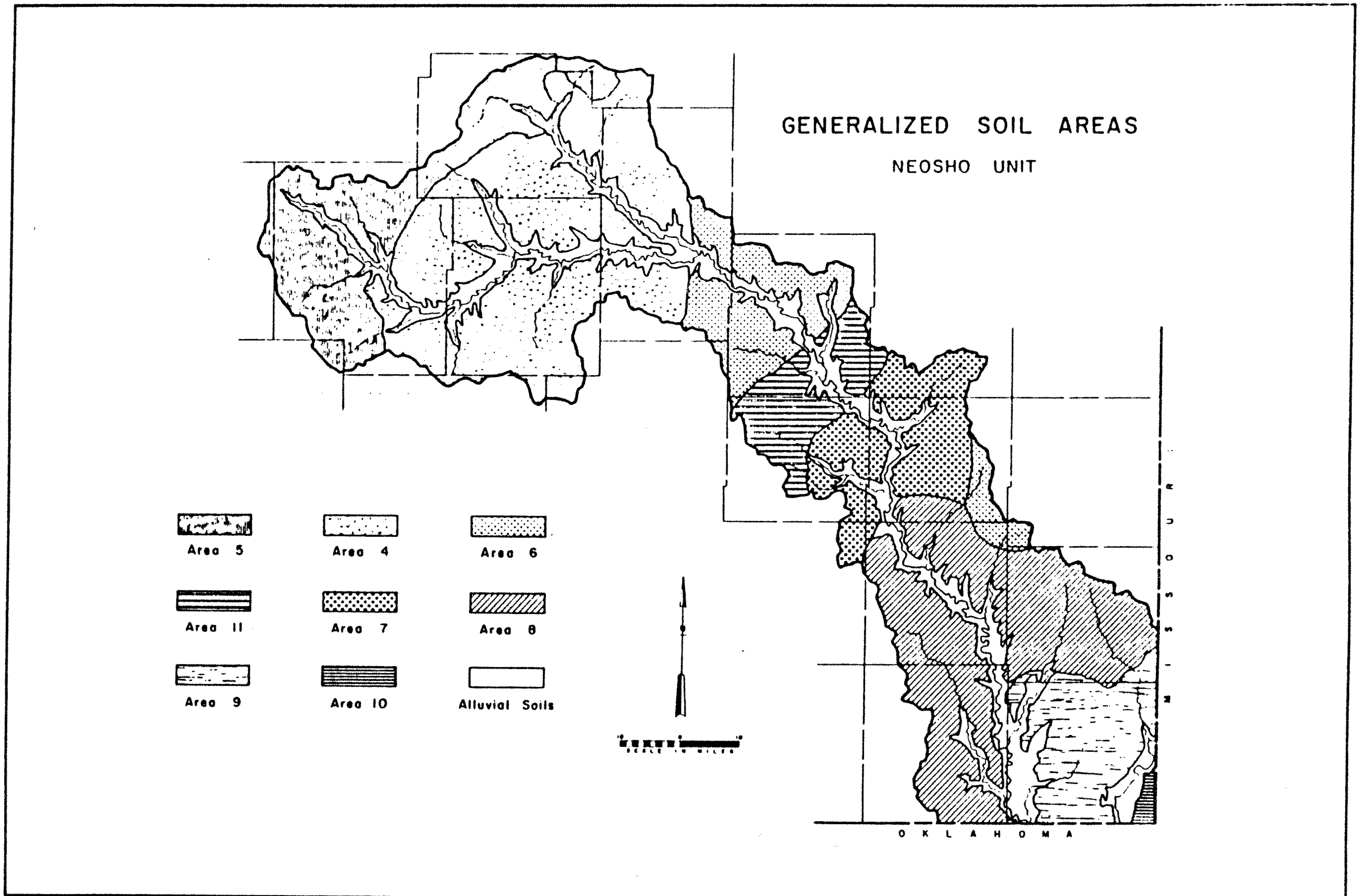


Figure 4. Generalized soil areas of the Neosho Unit of the Grand Lake River basin in Kansas (KWRB, 1961).

Table 3. Generalized soil areas for Neosho River and Spring River basins, Kansas (KWRB 1961).

Map ID	Description	Geographic Area (mi^2)	% Total (Kansas)
Area 4	Loess-covered ridgetops, easily eroded, developed from limestone and shales, hilly, relatively shallow	1484	24.2
Area 5	Fine textured, level to undulating, low permeability, best for wheat	756	12.3
Area 6	Silt loams, level to undulating,	512	8.3
Area 7	Silt loam, low permeability, acidity, nutrient deficient, highly erodible	452	7.4
Area 8	Silt loam on level on undulating with some poorly drained claypan soils, low fertility	1136	18.5
Area 9	Dense claypan soils from sandstone and sandy shales, permeable	404	6.6
Area 10	Stony, shallow, low fertility, strongly acid in reaction, rolling to hilly topography	24	0.4
Area 11	Sandy and silt loam from sandstone and shale, shallow, acidic, low fertility, highly erodible	288	4.7
Alluvial Soils	Highly permeable, most productive	1080	17.6
Total			100.0

Table 4. Outcropping geologic formations in the Neosho River and Spring River basins, Kansas (KWRB 1961).

System	Group	Area (mi^2)	% Total (Kansas)
Tertiary	Ogallala Formation	32	0.5
Cretaceous	Kiowa Shale	84	1.3
Permian	Sumner	720	11.6
Permian	Chase	960	15.4
Permian	Council Grove	548	8.8
Permian	Admire	148	2.4
Pennsylvanian	Wabaunsee	368	5.9
Pennsylvanian	Shawnee	428	6.8
Pennsylvanian	Douglas	160	2.6
Pennsylvanian	Pedee	60	1.0
Pennsylvanian	Lansing	340	5.5
Pennsylvanian	Kansas City	780	12.5
Pennsylvanian	Pleasanton	76	1.2
Pennsylvanian	Marmaton	672	10.8
Pennsylvanian	Cherokee	780	12.5
Mississippian	not described	76	1.2
	KANSAS TOTAL		100.0

dark soils are primarily associated with the prairie plains and tall grass ecotypes. The Dennis-Bates soils are dark loamy and relatively well drained soils. The Parsons type soils contain contain higher percentages of clays and are less well drained. The Verdigris-Osage type soils occur commonly in the alluvial plains of the tributaries to the lower portion of the Neosho River, Spring River, and Elk River floodplains and bottomlands around Grand Lake. The Verdigris soil type is characterized by deep, dark-colored, silt-loam to clayey-loam which varies from moderately to well drained. The Osage soils also occur in the bottomlands, but more in the backwater areas since they are slowly drained and contain higher levels of clays.

The Bodine (Clarksville)-Baxter type of soils are most common in the Spring and Elk River portions of the Grand Lake drainage basin. These soils are characterized by a high percentage of chert fragments, low fertility, and rapid drainage capacity. These cherty soils are typical of the Ozark Uplands and exhibit a dominant ecotype vegetational association of post oak, hickory, red oaks, and some pine. These soils are also common in the vicinity of the lake.

Table 5. Soil composition and bedrock geology of Missouri portion of Spring and Elk rivers, (after Stout and Hoffman 1973).

River	Description	Area (mi^2)	% Total (MO only)
Spring	Thick, mostly cherty limestones (e.g. Burlington, St. Louis, etc.)	1697.6	57.4
Spring	Thin shales, sandstones, clays, and coals (e.g. Tebo coal, Bevier coal, Lagonda shale, etc.)	374.4	12.7
	SPRING RIVER TOTAL	2072.0	70.1
Elk	Thick, mostly cherty limestones, (e.g., Burlington, St. Louis, etc.)	789.4	26.7
Elk	Limestones, shales, sandstones, dolomites, (e.g., Bowling green dolomite, Grand Tower limestone, Grassy Creek shale, etc.)	88.6	2.9
Elk	Thick, cherty and shaley dolomites (Jefferson City, etc.)	7.6	0.3
	ELK RIVER TOTAL	885.5	29.9
	MISSOURI TOTAL	2957.5	100.0

TASK 4: Public Access

OBJECTIVE: To describe the public access to the lake including the amount and type of public transportation to the access points.

RESPONSIBILITY: OWRB and OSU

AUTHOR: Douglas P. Reed

METHODS: Maps

Consultation with GRAD Lake Patrol

Consultation with Grand Lake Association

Consultation with Oklahoma Tourism and Recreation Department

DISCUSSION: This section discusses three major topics: Grand Lake's access characteristics, facility characteristics and the responsibility for use of the lake. Highways, roads, and public transportation serving the Grand Lake area will be examined. Routes and distances from major population centers will be delineated.

Access Characteristics of Grand Lake

Grand Lake O' The Cherokees (Grand Lake) lies in the northeastern corner of Oklahoma in what is known as Green Country by Oklahomans (Figure 5). Grand Lake is formed predominantly in Delaware county OK, roughly ninety percent lies in that county, the majority of the remainder lies in Mayes county OK, including the Grand River Dam Authority's (Pensacola Dam) and in Ottawa county OK, including the confluence of the Neosho (Grand) and Spring rivers which form the head waters of Grand Lake. A very small portion lies in the extreme southeastern corner of Craig county, OK.

Please refer to the map of Grand Lakes's eighty kilometer region, Figure 6, for Grand Lake's location in the Four State Region and Oklahoma. The Four State Region is made up of the southeast corner of Kansas, the southwest corner of Missouri, the northwest corner of Arkansas and the northeast corner of Oklahoma and is primarily known for mining operations earlier in this century. Also refer to Figure 5 for the discussion of interstate

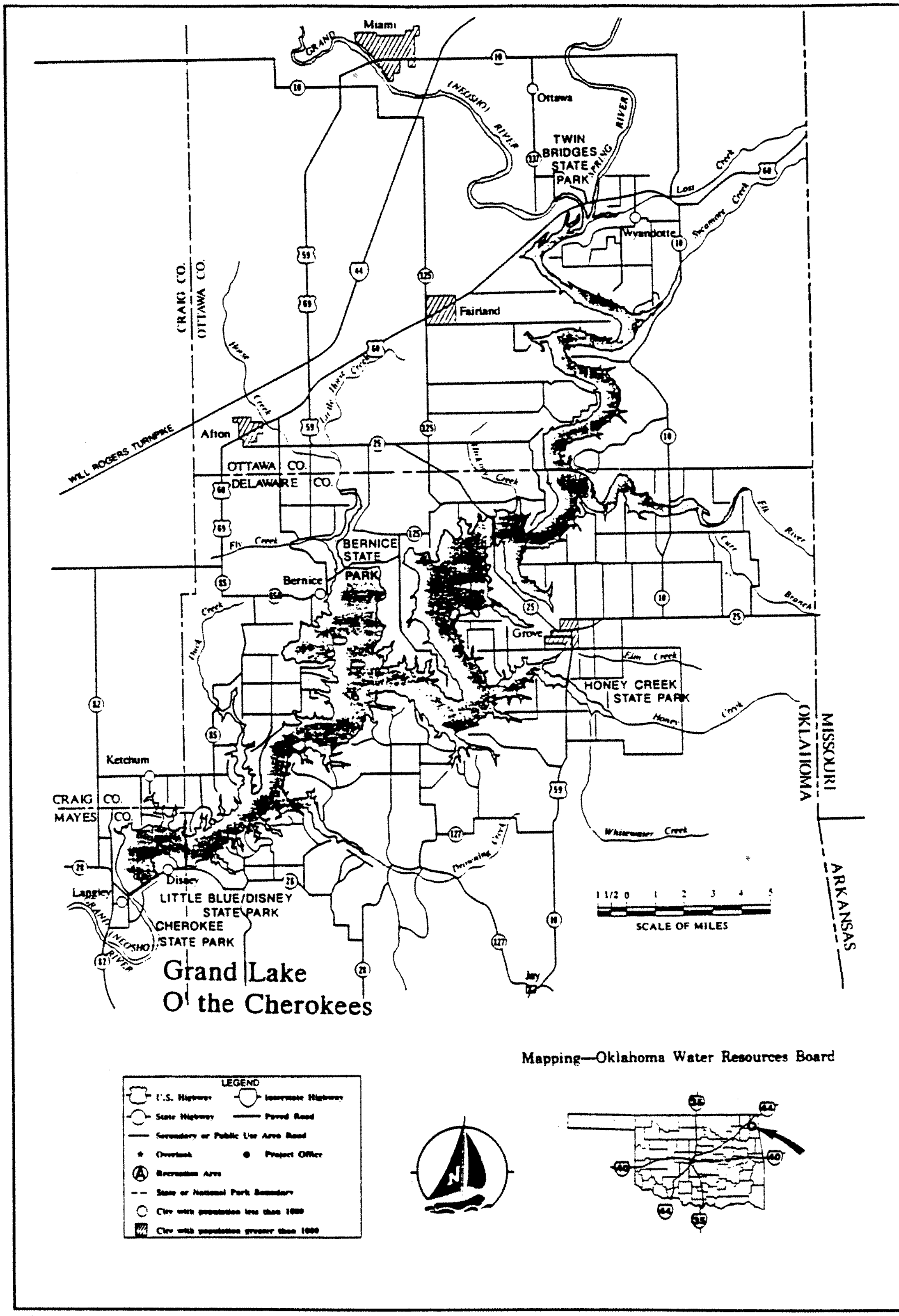


Figure 5. Map of the Grand Lake O' The Cherokees (OWRB).

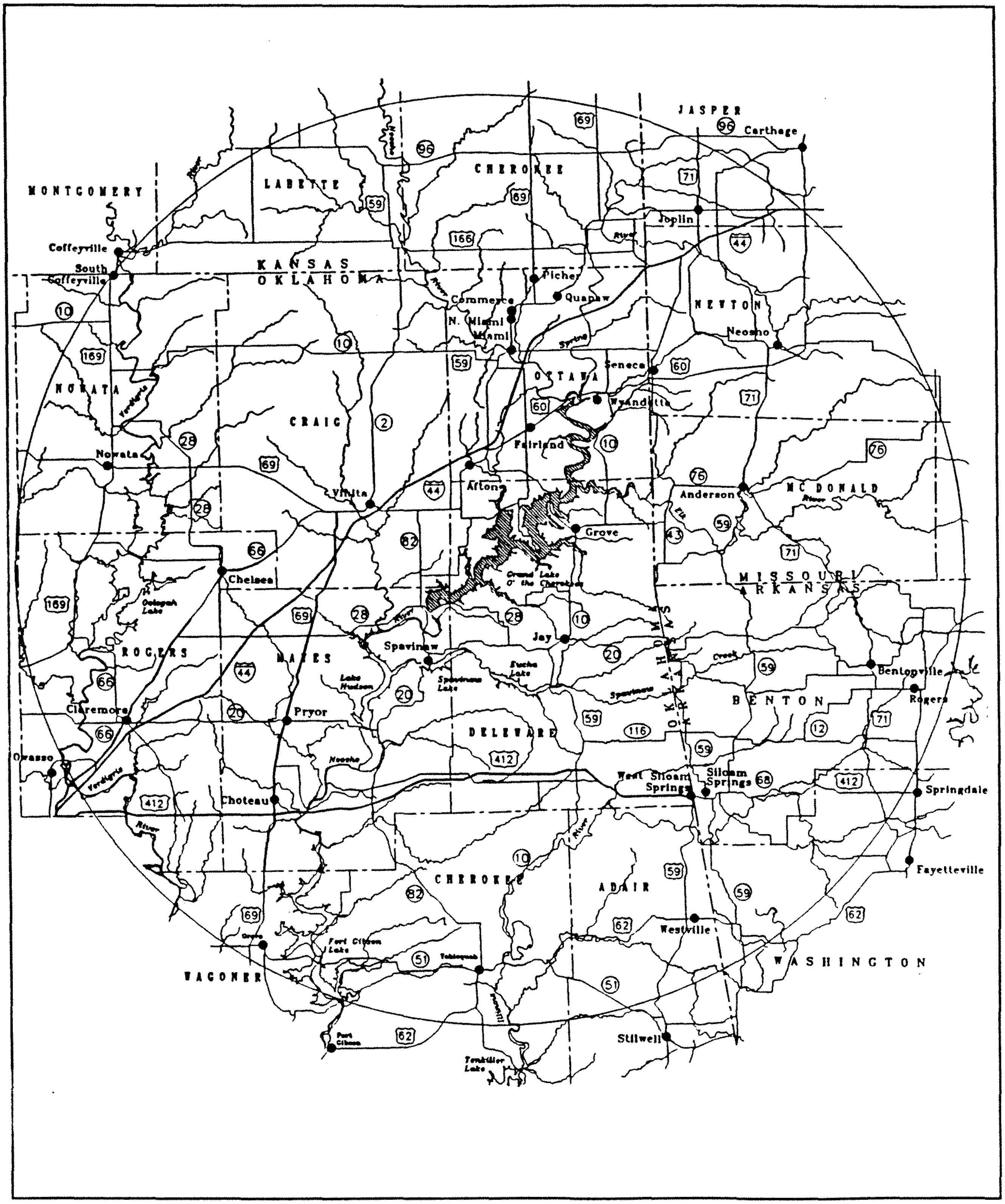


Figure 6. Map of the eighty kilometer region around Grand Lake with major cities, towns and roadways represented.

and United States highways in the region and for a detailed representation of the roadways serving the Grand Lake area and it's 1,300 miles of shoreline.

Routes and Distances from Major Population Centers

Grand Lake has several State and United States Highways that provide access to the Lake and the region. This geographical area is known as the Four State Region, (i.e., Kansas, Missouri, Arkansas and Oklahoma), and is within short road trips of several large metropolitan areas.

The major population centers that are within five hours driving time are as follows: Wichita, KS, 204 miles; Kansas City, MO, 205 miles; Springfield, MO, 115 miles; Tulsa, OK, 78, miles; Oklahoma City, OK, 184 miles; Fayetteville, AR, 75 miles; and Fort Smith, AR, 150 miles. These distances represent a hypothetical limit for regular travel to Grand Lake (i.e., over a long weekend) beyond this 200 mile radius regular weekend travel to Grand Lake is not practical. This is in part due to the abundant number of lakes in this geographical region which offer similar recreational activities with less travel time. However many vacation travelers visit Grand Lake from great distances and return to the area on successive trips. The extensive use of Grand Lake by vacation travelers is due to several characteristics of the lake, one important attribute that may contribute to this is the accessibility of the lake via numerous Federal, State and County highways, improved roads and country roads. The following discussion will examine the routes into the Grand Lake area from within the Four State Region and access to Grand Lake via the vast number of roadways surrounding the lake itself.

Highways and Roads Serving Grand Lake

Federal, State, County highways, improved roads and country roads serving the Grand Lake area are numerous due to the extensive shoreline (1,300 miles) of the lake. The following discussion will address each of these types of highways and roads starting with major four lane U.S. Highways, (i.e., Interstate 44, known as Will Rodgers Expressway, an OK toll road), then two and divided lane U.S. Highways, (i.e., U.S. Hwys 66, 60, 59, 69, 412), then State Highways, (i.e., State Hwys, 125, 10, 25, 137, 127, 28, 20, 82, 85 and 85A. The discussion will end with a description of various county, lake, and country road access routes.

Please refer to the map of the eighty kilometer region, Figure 6, and to the map of the Grand Lake region (Figure 5) for a detailed representation of the roadways serving the Grand Lake area.

U.S. Interstate Serving Grand Lake - U.S. Interstate 44 is the major national access to Grand Lake and runs parallel along the western shore of Grand Lake for its entire length. Interstate 44 or Will Rodgers Turnpike, as it is known between the Oklahoma state line and Tulsa, OK connects Joplin, MO and Oklahoma City, OK. This Interstate is a vital and well traveled highway that carries huge amounts of traffic. There are four separate exits on Interstate 44 between Tulsa, OK and Joplin, MO that Identify access to Grand Lake. At any point on the lake interstate 44 is less than a hour drive, however many locations on the lake are much closer.

Interstate 44 Interchanges - The first access from Interstate 44, starting at the northeast corner of Oklahoma and the north end of Grand Lake is the Miami, OK interchange. At this point OK State Hwy 10 heads east from Interstate 44 for ten miles and intersects OK State Highway 137. OK State Hwy 137 can be followed south for ten miles toward Grand Lake and Twin Bridges State Recreation Area.

The second access occurs at the Afton, OK interchange via U.S. Hwys 66, 69 and 59. At this point U.S. Hwy 59 turns to the southeast toward the north central part of the lake and away from the combined U.S. Hwys 66, 69 and 69 which head southwest toward the southern section of the lake.

The third access point occurs at the Vinita, OK interchange where U.S. Hwy 60 provides access to the western shore of Grand Lake and Bernice, OK. By following U.S. Hwy 60, 66 and 69 for fourteen miles east and intersecting with OK State Hwy 85 and 85a several sections of the western shore of the lake are accessible.

The fourth access point from Interstate 44 occurs at the Big Cabin, OK interchange where U.S. Hwy 69 intersects Interstate 44 and heads south to Big Cabin, OK where an intersection with a County road provides access to Ketchum, OK and the extreme southwestern shore of Grand Lake including Langley, OK and the Pennsacola Dam.

U.S. Highways Serving Grand Lake - (1) U.S. Hwy 66 (Route 66) provides access to Grand Lake for Miami, OK and points north of Miami, OK such as Galena and Baxter Springs, KS without Interstate 44 toll charges being assessed. In addition U.S. Hwy 66 southwest from Vinita, OK parallels Interstate 44 and allows for access to Grand lake from the Tulsa, OK area without Interstate 44 toll charges being assessed.

(2) U.S. Hwy 60 which runs east to west and stretches twenty miles across the northern part of Ottawa county passes over Grand Lake at the confluence of the Spring and Neosho (Grand) rivers. U.S. Hwy 60 and OK State Hwy 10 which intersect U.S. Hwy 60 at Wyandotte, OK provide access from Seneca, Neosho, and Joplin, MO without Interstate 44 toll charges being assessed, as well as Fairland and Miami, Oklahoma. U.S. Hwy 60 becomes U.S. Hwy 60,66,69 at the Afton, OK intersection. At the Vinita, OK intersection U.S. Hwy 60 continues to the west and provides access to Grand Lake for the Nowata and Bartlesville, OK areas.

(3) U.S. Hwy 69 is part of U.S. Hwy 66,69,59 that connects Columbus and Baxter Springs, KS, Miami and Afton, OK, to the north and Adair and Pryor, OK to the south. U.S. Hwy 69 is four lanes from Vinita to Muskogee, OK. It is possible to exit Interstate 44 at Claremore, OK and follow OK State Hwy 20 east to Pryor, OK and then follow U.S. Hwy 69 north to the Grand Lake area. However, this route would most likely be used to gain access to Lake Hudson and Lake Spavinaw, in Mayes county, OK or to Lake Eucha in southern Delaware county, OK.

(4) U.S. Hwy 412 (old OK State Hwy 33) connects the Tulsa, OK area with the Fayetteville, AR area, over a course of about one hundred and twenty miles. There is a current Oklahoma Department of Transportation project to

four lane U.S. Hwy 412 from it's intersection with U.S. Hwy 69 in Chouteau, OK to the Arkansas state line. When this project is done it will improve access to Grand Lake from points to the southeast and southwest. OK State Hwy 20 north from Locust Grove, OK in Mayes county can be used to gain access to the southern part of Grand Lake, however it is more likely to be used for access to Lake Hudson and Lake Spavinaw, in Mayes county, OK or to Lake Eucha in southern Delaware county. About twenty-five miles further east, U.S. Hwy 412 intersects the combination of U.S. Hwy 59 and OK State Hwy 10 near Kansas, OK. Access via this route is discussed below.

(5) U.S. Hwy 59 is part of combined U.S. Hwy 66,69,59 that connects Parsons, KS, Miami and Afton, OK. U.S. Hwy 59 turns east upon entering Delaware county, OK and heads toward Grand Lake and Grove, OK. It is ten miles from Interstate 44 to Grand Lake and seventeen miles to the town center of Grove, OK. At the town center of Grove, OK U.S. Hwy 59, in combination with State Hwy 10, turns south along Grand Lake's eastern shore thirteen miles to Jay, OK, the Delaware county seat. U.S. Hwy 59 continues twenty-one miles south through Delaware county, OK to an intersection with U.S. Hwy 412, near Kansas, OK. From this southern position in Delaware county, OK U.S. Hwy 59 provides access to the southeastern section of the lake for individuals traveling U.S. Hwy 412 from points east of Siloam Springs, AK including the Springdale and Fayetteville, AR areas. In Oklahoma access is provided by U.S. Hwy 59 for Mayes, Cherokee and Adair county travelers that use U.S. Hwy 412 east. There are other routes (i.e., State Highway 20) from Mayes county that are often used, these and other routes will be discussed in the following section on State highway access to Grand Lake.

State Highways Serving Grand Lake - (1) OK State Hwy 125 provides access to Grand Lake for Miami, OK travelers and all connecting roads in the Miami area. OK State Hwy 125 runs south from Miami, OK for twelve miles to Fairland, OK, where it intersects with U.S. Hwy 60, and continues south for five miles to an intersection with the combination of U.S. Hwy 59 and OK

State Hwy 10. OK State Hwy 125 continues south for four miles to an intersection and origin of OK State Hwy 85A, then continues south for six miles to Monkey Island, OK and ends at Shangri-la Resort, Monkey Island, OK.

(2) OK State Hwy 10 comes into Miami, OK from the west allowing access for the Coffeyville and Independence, KS areas to the north end of Grand lake. At the Welch, OK intersection with the combination of OK State Hwy 2 and U.S. Hwy 59 travelers can proceed south on OK State Hwy 2 for seventeen miles to Vinita, OK which allows for access to the west central part of Grand Lake. Otherwise travelers can proceed twelve miles east on the combination of OK State Hwy 10 and U.S. Hwy 59 to the Dotyville, OK intersection with the combination U.S. Hwy 66, 69 where U.S. Hwy 59 joins these and turns to the south and an intersection with Interstate 44 which allows access to the northwest part of Grand Lake. OK State Hwy 10 continues east to Miami, OK and intersects Interstate 44 four miles east of Miami, OK and then continues east five miles to an intersection with OK State Hwy 137, which heads south six miles to the confluence of the Neosho (Grand) River and Spring River which form the head waters of Grand Lake. OK State Hwy 10 continues five miles east and then turns south five miles to Wyandotte, OK where it intersects with U.S. Hwy 60 and then continues south sixteen miles along the eastern shore of Grand Lake which allows for access to the northeast part of Grand Lake. About sixteen miles south of this intersection, during which there are numerous access points to Grand Lake's northeastern shore via state and county roads, OK State Hwy 10 intersects with OK State Hwy 25 which runs five miles from the Missouri state line and an intersection with MO State Hwy 43 to the intersection mentioned above. MO State Hwy 43 runs north to south connecting Seneca and Southwest City, MO, about thirty miles, and intersects OK state Hwy 25 four miles south of Tiff City, MO which provides access to the Grove, OK area and northeast central Grand Lake for the extreme southwestern corner of Missouri. OK State Hwy 10 turns west at the intersection OK State Hwy 10 and 25 and proceeds three miles to Grove,

OK where it combines with U.S. Hwy 59 heading south thirteen miles to Jay, OK. OK State Hwy 10 provides access to the Zena and Grove, OK, south central and southeastern Grand Lake areas for points south and west of Jay, OK. OK State Hwy 10 in combination with U.S. Hwy 59 continue south for seventeen miles from Jay, OK to an intersection with OK State Hwy 116 which stretches eleven miles west from the Arkansas state line and AR State Hwy 43. State Hwy 10 in combination with U.S. Hwy 59 continue south for four miles and intersect U.S. Hwy 412 (old OK State Hwy 33) near Kansas, OK. U.S. Hwy 59 turns to the east in combination with U.S. Hwy 412 and OK State Hwy 10 continues south for twenty-six miles to Tahlequah, OK. This route provides access for the Tahlequah, OK area to the southern end of Grand Lake.

(3) OK State Hwy 137 heads south for five miles from its intersection with U.S. Hwy 69 in northern Ottawa county and passes under Interstate 44. It then intersects with OK State Hwy 10 and heads south six miles to the confluence of the Neosho (Grand) River and Spring River which form the head waters of Grand Lake were it intersects U.S. Hwy 60 and ends.

(4) OK State Hwy 127 heads north ten miles from Jay, OK to Zena, OK where it turns back to the east for seven miles to an intersection with the combination of U.S. Hwy 59 and OK State Hwy 10. OK State Hwy 127 provides access to the south central (Zena Area) of Grand Lake fo. individuals traveling south from Grove, OK or north from Jay, OK.

(5) OK State Hwy 28 heads south for six miles from its intersection with U.S. Hwy 66 in Chelsea, OK and then turns to the east for five miles and passes under Interstate 44. It continues east for five miles and intersects U.S. Hwy 69 at Adair, OK and continues east for eight miles to Pensacola, OK and another five miles east to Langley, OK where it intersects with OK State Hwy 82. It continues east out of Langley, OK and into central Delaware county OK for twelve miles where it intersects OK State Hwy 20 near New Eucha, OK. This route provides access to the extreme southern end of the lake for

travelers from the Jay, OK area and points east as well as travelers from the Adair, OK area and points west.

(6) OK State Hwy 20 starts in the extreme southern corner of MO (i.e., Southwest City, MO), where it crosses the MO state line and changes from MO State Hwy 43 to OK State Hwy 20, and then heads south for five miles where it intersects with AR State Hwy 72 near Maysville, AR and turns to the west eleven miles to Jay, OK. OK State Hwy 20 intersects the combination of U.S. Hwy 59 and OK State Hwy 10 in Jay, OK and continues to the west for eleven miles to Chloeta, OK and another five miles southwest to the intersection with OK State Hwy 85 and two miles south to Spavinaw, OK. Continuing south for thirteen miles to Salina, OK in combination with OK State Hwy 85, it then turns to the west splitting off from OK State Hwy 85 and crossing Lake Hudson. It then runs west for ten miles to Pryor, OK where it intersects with U.S. Hwy 69 and continues west another seventeen miles to Claremore, OK and an interchange with Interstate 44. OK State Hwy 20 provides access for travelers from the Pryor, OK area and points west (i.e., Claremore, OK) and for travelers from the Jay, OK area and points east (i.e., extreme southwest MO and extreme northwest AR).

(7) OK State Hwy 82 heads south for seven miles from its origin at the intersection with U.S. Hwy 60 near Vinita, OK, to an intersection with OK State Hwy 85. It continues south for three miles to Langley, OK and another five miles south to an intersection with OK State Hwy 20 which combines with it and continues south two miles to Spavinaw, OK. The combination of OK State Hwys 20 and 85 continue south for thirteen miles to Salina, OK where OK State Hwy 85 splits from OK State Hwy 20 and continues south for seven miles to Locust Grove, OK where it intersects with U.S. Hwy 412. It then continues south for nine miles to Peggs, OK and another seven miles to Gideon, OK. It continues nine miles further to Tahlequah, OK.

OK State Hwy 82 provides access to the extreme southern end of Grand Lake for travelers using OK State Hwy 20 from Pryor, OK and points west, for travelers using U.S. Hwy 412, and for travelers from the Tahlequah, OK area. OK State Hwy 82 also provides access to the south central area of Grand Lake (i.e., Ketchum, OK area) via OK State Hwy 85 for travelers from the Vinita, OK area and points northwest of Vinita, OK.

(8) OK State Hwy 85 starts at it's intersection with U.S. Hwys 66, 69, 60 and heads south for one mile and then turns to the east for two miles where it turns to the south and splits off from OK State Hwy 85A. It continues south for three miles to Cleora, OK and continues another five miles to Ketchum, OK where it heads to the west for two miles and Grand Lake Towne, OK. It continues west for two miles beyond Grand Lake Towne, OK to an intersection with OK State Hwy 82 ten miles south of Vinita, OK.

OK State Hwy 85 provides access to Grand Lake's southwest central shore line and the Ketchum, OK area. Travelers from the Vinita, OK area and points north as well as travelers coming from the Langley, OK area and points south can gain access to this area of the lake by using OK State Hwy 85.

(9) OK State Hwy 85A starts as it splits off of OK State Hwy 85 three miles north of Cleora, OK, heading to the east for seven miles to Bernice, OK. It continues to the northeast from Bernice, OK for two miles when it intersects with OK State Hwy 125 nine miles south of Fairland, OK.

OK State Hwy 85A provides access for travelers to the Bernice, OK area of Grand Lake's west central shore. Travelers using OK State Hwys 125 and 85 can gain access to Grand Lake's west central shore line as well as Monkey Island, OK via OK State Hwy 125 south.

Country and Improved Roads Serving the Grand Lake Area - Due to the large number of secondary roads networking the Grand Lake shore line a detailed discussion is precluded, however several points need to be noted that should help the reader understand this situation and gain insight from the maps provided.

The focus should be on those lake roads that lead directly or indirectly to the lake's shore. The development on other secondary roads in the area tends to be dominated by agricultural interests that do not depend on the lake for continuation.

The secondary roads of interest vary in composition and development along their routes due to several factors, which include: (1) proximity to larger communities and OK State Hwys or U.S. Hwys; (2) whether the road is asphalt or dirt; (3) the relative distance from the dam; and (4) the extent to which shoreline property access is controlled due to private ownership.

A final point that should be noted in reference to these secondary roads is the fact that many of the old routes that existed before the dam was constructed serve as access points for the public to launch boats, etc. This issue will be discussed in the section on public access points to Grand Lake.

Public Transportation Serving the Grand Lake Area

There are no public transportation services in the area adjacent to Grand Lake. The communities surrounding the lake are small and therefore do not present large enough markets to support bus lines or passenger rail service. There is one local bus service with limited range and capacity intended for use by the elderly in the area. This service, Pelivan, is operated by the local Area Agency on Aging and can be used by the general public for one dollar per ride. This service does not connect cities or towns and does not deliver passengers directly to the lake shore. It is intended to provide transportation for the elderly who are unable to drive and any other individual with similar needs. It is operated on a non-profit basis.

There are several small airports and one seaplane base serving the Grand Lake area. The Miami, OK airport being the largest with a 5,600 foot paved runway and FBO facilities. Other airports in the area relative to their facilities are as follows: Grove, OK airport with a 4,000 foot paved runway and FBO facilities; Shangri-La airport with a 4,000 foot paved runway and FBO facilities; Vinita, OK airport with a 2,850 foot paved runway and no FBO facilities; Ketchum, OK airport with a 3,000 foot grass runway and no FBO facilities; and Port Cherokee Seaplane Base. The closest major airport is located in Joplin, MO, about twenty five miles from the head waters of Grand

Lake and about seventy five miles from the dam. There is a major regional airport located in Tulsa, OK, sixty-five miles from the dam.

Facility Characteristics of Grand Lake

Public Access Points to Grand Lake

Grand River Dam Authority has control over all property up to an elevation of 750 msl on Grand Lake and allows free public access to these lands. There is no charge to the public for the right to engage in hunting, fishing, swimming or non-commercial boating. No camping is permitted on GRDA property except in areas designated as public use areas. There are different taking elevations in the upper end of Grand Lake that alter this control however these are not significant in terms of public access.

There are two general types of public access points which allow for boating, fishing and other water sports, in some combination of these three types of activities. The two types include: (1) state park access points; and (2) public access points that are not supported by the state. The various commercial facilities available to the public will be discussed in a following section . Please refer to Figure 5 discussion of public access points on Grand Lake.

State Park Access Points

There are seven public access points associated with the five state supported park areas on Grand Lake. These state park areas include Bernice State Park, Cherokee State Park Areas 1, 2 and 3, Disney State Park/Little Blue, Honey Creek State Park and Twin Bridges State Park. The following discussion describes the characteristics of each of these state parks.

Bernice State Park is located on Hwy 85A at Bernice, OK on the Horse Creek arm of Grand Lake and covers eighty-eight acres of state owned property in Delaware county OK. The site allows for fishing, swimming and boating with one lighted boat ramp. Other facilities include twenty-one picnic tables, thirty-three electric hookups for camping and twenty unimproved camping sites, one comfort station with showers, one comfort station without showers, one sanitary dump station and one playground.

Cherokee State Park Areas 1, 2 and 3. Cherokee # 1 is located on the south side of Langley, below Pensacola Dam on the Grand River and allows for fishing and boating with one lighted boat ramp. Other facilities include twenty-eight picnic tables, one group shelter, eighteen electric hookups for camping, forty unimproved camp sites and one comfort station without showers.

Cherokee # 2 is located on the east end of Pensacola Dam and allows for fishing, boating and other water sports with one lighted boat ramp. Other facilities include twenty-two picnic tables, one group shelter, twelve electric hookups for camping, twenty-five unimproved camp sites, one comfort station with showers, one sanitary dump station and one playground.

Cherokee # 3 is located one half mile east of Pensacola Dam beside the east spillway and the site allows for fishing, boating and other water sports with one lighted boat ramp. Other facilities include twenty picnic tables, one group shelter, four electric RV sites and twenty unimproved RV sites, one comfort station with showers, one sanitary dump station

The total state owned acreage included in the three Cherokee sites is forty-three. All three sites are located in Mayes county OK.

Disney State Park/Little Blue, the Disney site is located on OK State Hwy 28 south of Disney, OK below the spillway and allows for fishing and boating with one lighted boat ramp. There are twenty-eight picnic tables, four individual shelters, one group shelter, twenty-five unimproved RV sites and one playground. Disney state park covers twenty acres of state owned property.

The Little Blue site is located below the spillway. No large motors are allowed in this area, only fishing boats with small trolling motors. There are ten picnic tables and fifteen unimproved RV sites. Little Blue covers twelve acres of state owned property.

Honey Creek State Park is located in Grove, OK one mile west off of U.S. Hwy 59 on State Park road and allows for fishing and boating with one lighted boat ramp. There are ninety-seven picnic tables, two group shelters, fifty-six semi-modern (electric) camp sites, eighty unimproved camp sites, two comfort stations with showers, one comfort station without showers, one sanitary dump station, one swimming pool with bathhouse (leased to and maintained by the city of Grove, OK, one playground and one lessee on site that rents boats, motors, paddleboats, jet skis and operates a snack bar. The Honey Creek site covers thirty acres of state owned property.

Twin Bridges State Park is located seven miles east of Fairland, OK on U.S. Hwy 60 and allows for fishing and boating with two lighted boat ramps and one unlighted boat ramp. There are ninety-two picnic tables, nine individual shelters, four group shelters, seventy-six semi-modern (electric) camp sites, one hundred unimproved camp sites, two comfort stations with showers, two comfort stations without showers, one sanitary dump station, one volleyball court, two horseshoe pits, three playgrounds and one lessee on site that operates an enclosed fishing dock, rents paddleboats, canoes, boats, motors, sells bait, tackle and gas. The Twin Bridges site covers sixty-three acres of state owned property.

Non-State Supported Access Points

There are ten public access points with boat launching facilities on Grand Lake that are not state supported. They are either county or community supported and the majority of these are located on the eastern shore of Grand Lake. Those situations where communities maintain boat launching facilities, as the town of Grove, OK does on the Wolf Creek arm of Grand Lake, are few and far between and do not contribute extensively to overall lake usage. In addition to these ten access points there are an additional sixteen public access points that do not maintain boat launching facilities on Grand Lake. They are either county or community supported and are used for fishing, swimming and other non power boat related activities.

Other public access points can be found around the lake shore which are not identified as maintained boat launch sites. These access points result from the corresponding right of ways associated with old roadways that were covered by the lake. These road beds and the roads associated with them allow for public access due to state or county ownership of these lands to the taking level of the Grand River Dam Authority. Not only are these types of access points numerous but they are also largely undocumented. They are however utilized by the public and should be considered when assessing the overall usage of the lake. It should be understood that although these sites are utilized by the public the relative contribution of these sites to overall lake use is hard to estimate. With the large number of well maintained boat launch sites, commercial, public and private, it is reasonable to say that these undocumented sites contribute little to overall lake use.

Types and Sizes of Private and Commercial Access Points

There are 3315 private docks and 134 commercial docks registered on Grand Lake. The large number of commercial and private docks and access points reflect the open use of the shoreline of Grand Lake. This situation is the result of control of the shoreline by the Grand River Dam Authority rather than the Corps of Engineers which, in many cases, limits shoreline development. The Authority's regulations allowing for extensive development of the shoreline along with the lengthy history of Grand Lake (fifty years) has produced the dense settlement pattern (number of homes) and large number of commercial businesses along the shoreline of Grand Lake.

Private Access Points - Due to the large number of private docks (3315) on Grand Lake and the variation in type and size, a detailed examination of these docks is precluded. Based on consultation with the Lake Patrol most private docks are located on the southern two thirds of the lake. This is due to the nature of the lake (which tends to be deeper and wider closer to the dam) and due to the relative proximity of the southern sections of the lake to larger population centers (i.e., Langley, Ketchum, Grove, and Jay, OK).

Commercial Access Points - Due to the large number of commercial docks (134) the discussion will focus on 32 major commercial marinas operating on Grand Lake. The following is a discussion of the facilities available and location of each of these marinas.

(1) Anchor's End - Located south of Ketchum, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, heated fishing dock and cottage rentals.

(2) Arrowhead Yacht Club - Located east of Ketchum, OK with facilities for complete marine service, including sales and storage, and a full service marina.

(3) Ballerina Pier 59 - Located north of Grove, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, camping, resale of boats, heated fishing dock and cottage rentals.

(4) Barker's Edgewater Marine - Located northwest of Grove, OK with facilities for boat launching, swimming, mobile home rental, sale and resale of boats and motors.

(5) Blue Bluff Harbor - Located northeast of Grove, OK with facilities for mobile home lots, heated fishing dock, boat launching, wet boat storage and construction of docks.

(6) Cherokee Yacht Club - Located on Duck Creek, with full service country club environment, including swimming pool, tennis court, dining and party facilities and a full service marina.

(7) Coons Marine - Located north of Grove, OK with facilities for inside and outside boat storage, repairs, sales of new and used boats and motors and boat launching.

(8) Courthouse Marina - Located south of Grove, OK with facilities for boat rentals, boat launching, swimming, sale and resale of boats, heated fishing dock, cottage rentals, covered boat slips, full service dock and ski shop.

(9) Dick Lane Kawasaki-Yamaha, Port Carlos - Located east of Ketchum, OK with facilities for jet ski rental and boat launching.

(10) Elk River Marina - Located northeast of Grove, OK with facilities for sale and resale of boats and motors, repairs and boat launching.

(11) Elk River Paradise - Located northeast of Grove, OK with facilities for Boat storage, full marine service, mobile home and RV park, convenience store, boat rental, boat launching, sale and resale of boats and motors.

(12) Four Seasons - Located northeast of Grove, OK with facilities for RV hook ups, boat launching, heated fishing dock, boat slips, swimming, laundry, convenience store, game room, boat rentals and rental cabins.

(13) Grand Lake Charter and Rentals - Located on Honey Creek State Park, Grove, OK with facilities for boat launching, charter service and boat rentals.

(14) Harbors View Marina - Located southeast of Cleora, OK with facilities for boat and motor sales and repair, full service marina and boat launching.

(15) Hi-Lift Marina - Located east of Disney, OK with facilities for dry dock storage, covered slips, ships store, sales, service and full service marina.

(16) Hills Resort - Located south of Grove, OK with facilities for cottage rental, swimming, boat and motor rental, covered dock, wet and dry dock, boat launching, convenience store, fishing guide service and heated fishing dock.

(17) Honey Creek Resort - Located on south Main St. Grove, OK with facilities for cottage rentals, boat dock, boat launching, swimming, enclosed fishing dock, fishing pier, boat rentals, fishing guide, motel and airport pick-up.

(18) Indian Hills Resort - Located in Bernice, OK with facilities for cottage rental, swimming, boat launching, heated fishing dock, convenience store, full service marina, boat and motor rental, RV hookups and snack bar.

(19) Jerry's Marina and Storage - Located in Bernice, OK with facilities for lift repair, barge service, dock construction, boat sales, wet slips, dry storage and boat launching.

(20) King Point Resort - Located northeast of Grove, OK with facilities for mobile homes, cottage rental, boat and motor repairs, swimming, heated fishing dock, dry boat storage, RV hookups, boat launching and convenience store.

(21) Lee's Resort - Located northeast of Grove, OK with facilities for mobile homes, RV hookups, cottage rental, boat launching, covered docks, boat rentals, heated fishing dock, swimming pool, tennis courts, playground and convenience store.

(22) Long's Resort - Located west of Grove, OK with facilities for cottage rental, boat launching, heated fishing dock, boat slips and convenience store.

(23) Monkey Island East Bay - Located on Monkey Island with facilities for cottage rentals, mobile homes, slips, full service marina and boat launching.

(24) Out of the Ordinary at Pier III - Located south of Grove, OK with facilities for cottage rental, boat rental, ships store, covered boat slips, restaurant, full service marina and boat launching.

(25) Pla-Port Resort - Located in Grove, OK with facilities for mobile homes, swimming, playground, recreation hall, complete marine service, RV hookups, wet and dry docks, boat and motor rentals, heated fishing dock, cabin rental and boat launching.

(26) Port Duncan - Located on Monkey Island with facilities for sale of condos, lots, houses, cottage rental, boat slips, full service marina, ships store and boat launching.

(27) Port Ketchum - Located south of Ketchum, OK with facilities for cottage rental, meeting room, boat slips and boat launching.

(28) Red Rock Resort - Located north of Grove, OK with facilities for RV hookups, camping, convenience store, boat launching, enclosed fishing dock, slips, swimming pool and motel and cabin rental.

(29) Scotty's Cove - Located north of Langley, OK with facilities for full service marina, boat slips and boat launching.

(30) Shangri-La Marina - Located on Monkey Island with facilities for boat rental, full marine service, boat launching, wet storage, ships store and fishing guide service.

(31) Slim's Resort - Located east of Cleora, OK with facilities for overnight lodging, RV hookups, mobile homes, convenience store, cafe, boat launching, ships store, boat rentals and slips.

(32) TeraMiranda Marina-Resort - Located on Monkey Island with facilities for cottage rental, tennis courts, swimming pool, playground, boat launching, slips, full service marina and boat sales.

Responsibility for Use of Grand Lake

Grand River Dam Authority was created in 1935 by an act of the Oklahoma Legislature as a cost-of-service, non-tax- supported agency of the State of Oklahoma. As a conservation and reclamation district, the authority has power to control, store, preserve, distribute and sell the water of the Grand River. In addition it has the power to develop, generate, buy, sell and distribute electric power and electric energy as well as to construct, extend and maintain facilities on GRDA right-of-ways.

Rules and Regulations

Grand Lake is controlled by the Grand River Dam Authority which has established it's own rules for lake use. In addition to these rules U.S. Coast Guard regulations and the State of Oklahoma lake rules also apply.

State of Oklahoma Lake Rules - The Oklahoma Boating Act of 1981 applies to all GRDA lakes. The rules include the following requirements: (1) all boats must be licensed by July 31 of each year; (2) all federally documented boats must be registered in the State of Oklahoma, boats with other state licenses are allowed to operate on GRDA lakes for periods of less than sixty days without an Oklahoma state license; (3) registration stickers must be displayed on the front port and starboard portion of the vessel; (4) in boats smaller than twenty-seven feet all children under twelve years must wear an approved life preserver at all times; and (5) additional requirements per the United States Coast Guard regulations.

GRDA Lake Rules - In addition to Oklahoma and Federal rules and regulations there are additional rules that apply on GRDA lakes and Grand Lake in particular. (1) All boats kept or operated on GRDA lakes shall be inspected by the Authority's Lake Patrol and a safety inspection sticker shall be placed on the port front portion of the boat; (2) within one hundred yards of boats, wharfs, docks, shoreline, landings or swimming area, power boats and jet skis must not travel faster than idle speed and all boats shall respect the "No Wake Area" under all bridges on Grand Lake; (3) Water skiing, jet skiing and similar activities are permitted only during daylight hours and all skiing (including jet skis, water bikes and similar craft) is prohibited upstream from the Strang bridge; (4) operators of jet skis, water bikes and similar craft must stay at least twenty-five feet away from all moving vessels and must idle around docks and swimmers, all operators must wear an approved life preserver (personal flotation device); (5) in addition to the boat operator, a boat towing a skier must have a person (eight years old or older) in a position to observe the skier, unless a rear mirror has been installed in such a position that the boat operator can observe the skier; (6) all boats must carry an approved life preserver (personal flotation device) for each person on board, no boat shall be permitted to operate on the lake when it is laden beyond its licensed capacity, each boat shall be equipped with a paddle or set of oars, anchor and a bailing device, all boats over 16 feet in length must have a throwable cushion, no sirens are permitted, and all boats must have proper navigation lights and fire extinguisher; (7) firearms are prohibited on or around the lake except during duck hunting seasons, with shotguns being permitted during this season only; (8) during nighttime hours, boat speeds bust be less than half throttle and lights must be illuminated at all times; (9) boats must not be operated within five hundred feet of any GRDA dam, no boat may be operated in a reckless or unsafe manner, and no boat may be operated by a person under the influence of alcohol or drugs; and (10) inspection stickers may be canceled and boats removed from the water of GRAD lakes for any violation of these rules.

These rules and regulations represent the most commonly asked questions concerning use of Grand Lake. For a more extensive discussion of the rules for the use of Grand Lake including the shore lands please refer to Appendix B (Rules and Regulations for Use of Grand Lake).

Hours of Operation, Fees and Seasonal Limits on Lake Use Hours of Operation - Grand Lake is open to the public for use twenty-four hours a day. This is provided that the individual using the lake abides by the rules and regulations set forth in the Grand River Dam Authority's handbook.

Fees and Permits - There are several different types of fees assessed by the Grand River Dam Authority. These include commercial fishing permits, commercial dock permits, private dock permits and various other assessed fees for lake use.

Commercial fishing permits are issued by special application and a permit is required with fees determined in each individual case. Currently there are two commercial fishing permits issued for the entire lake. Based on conversations with the Lake Patrol these operations are not large scale and are probably not likely to continue for much longer.

Commercial dock permits cover all floating structures other than private. Currently there are one hundred and thirty-four commercial docks on Grand Lake. Commercial floating structures will pay $.035 per square foot, but not less than forty dollars on an annual basis. The square footage is obtained by the outside dimensions of the dock or facility.

Other commercial facilities are assessed annual fees as follows: (1) boat ramps, fifty-five dollars; (2) marine railways, fifty-five dollars; (3) barges and other commercial crafts, one hundred dollars. In addition to these fees and permits the Authority may issue licenses and permits for the construction, operation, maintenance, or use of any other facility of facilities not specifically covered above by application to the Authority.

Private docks are assessed fees on an annual basis dependent upon the size of the dock. Currently there are 3315 private docks on Grand Lake. These are defined as a floating structure 1,100 square feet or less designed for private use and not related to the generation of revenue. Private docks are assessed an annual fee of sixteen dollars plus six dollars for each boat slip over one. Those private docks over 1,100 square feet in size will be assessed annual fees based on commercial rates excluding the minimum rate of forty dollars.

Dredging permits are issued for a fee of thirty dollars with a thirty dollar assessment for each renewal.

Domestic water permits are issued for the use of water by an individual or by a single family household for household, garden, or irrigation purposes, but not exceeding three acres in area. The permit fee is ten dollars plus an annual usage fee of eighteen dollars per year. See Appendix A for a complete list of fees for Grand Lake.

Seasonal Limits on Lake Use - There are no specific seasonal limits on lake use other than the hunting restrictions mentioned above. However based on conversations with the GRDA Lake Patrol lake usage declines significantly during the winter season. The winter season is defined as the time period between Labor Day and Memorial day. The GRDA Lake Patrol estimates that as little as one third as many individuals use the lake during this time period.

Appendix A

Rules and Regulations for Use of Grand Lake

Fee Schedule for Grand Lake

TASK 5: Adjacent Population

OBJECTIVE: Description of adjacent population centers to assess potential increase in use of recreational opportunities, if lake was cleaned up.

RESPONSIBILITY: OWRB and OSU

AUTHOR: Douglas P. Reed

METHODS: Census Data

Consultation with Grand Gateway Economic Development Association

Consultation with Grand Lake Association

Consultation with Oklahoma Tourism and Recreation Department

DISCUSSION: This section deals with the population characteristics of the Grand Lake region with respect to; A. the four state region, with focus on major population centers within an eighty kilometer radius and B. the four county region, by county, within which Grand Lake is formed.

Population Characteristics of the Grand Lake Region

Population characteristics of the four state region are presented to estimate the potential for increased usage of Grand Lake. The data focus on major population centers within an eighty kilometer radius of Grand Lake. The following tables present data on population for those counties and cities that fall within the eighty kilometer radius of Grand Lake. This radius represents the land area within which the hypothetical population of lake users resides. Due to the location of Grand Lake, in the extreme northeast corner of Oklahoma, the four states that are included in the eighty kilometer radius are: Kansas, Missouri, Arkansas and Oklahoma. Refer to Task 4, Figure 6 for spatial reference.

The following tabular information (Table 6 - Table 13) is derived from the County and City Data Book, 1988. Each of the four states are represented by two tables which include the following information: (1) the population, population density, total square miles of each county within the eighty kilometer radius, total state population, total identified county population and percent of state population in identified counties; (2) the population of significant towns and cities within the eighty kilometer radius and whether or not they lie within a Standard Metropolitan Statistical Area.

Sources:

County and City Data Book, 1988, United States

Department of Commerce, Bureau of the Census

Oklahoma Department of Tourism and Recreation, Park Visitor Survey, 1987

Table 6. Population of counties within eighty kilometer radium of Grand Lake.

County	1986 Population	Density	Total Sq. Mi.
Ottawa	33900	72.9	465
Craig	15100	19.8	763
Delaware	28000	38.9	720
Mayes	35000	54.3	644
Rodgers	55700	81.6	683
Cherokee	34800	46.5	748
Adair	19800	34.3	577
Nowata	11000	20.4	540
Total Counties	219710	42.8	5140
Total State	3305000	48.1	68655

% of State Pop. in counties = 6.6

Table 7. Population of Oklahoma cities within an eighty kilometer radius of Grand Lake.

City	1986 Population	MSA (Metropolitan Statistical Area)
Miami	14200	NO
Claremore	16290	YES
Vinita	6740	NO
Pryor	8400	NO
Talequah	12930	NO
Afton	2500	NO
Nowata	4110	NO
Chouteau	<2500	NO
Locust Grove	<2500	NO
Grove	3378	NO
Jay	<2500	NO

Table 8. Population of Kansas counties within an eighty kilometer radius of Grand Lake.

County	1986 Population	Density	Total Sq. Mi.
Labette	25,400	38.9	653
Cherokee	22,200	37.6	590
Total Counties	47,600	38.3	1,243
Total State	2,460,000	30.1	81,778

% of State Pop. in counties = 1.9

Table 9. Population of Kansas cities within eighty kilometer radius of Grand Lake.

City	1986 Population	MSA
Oswego	<2,500	NO
Columbus	3,410	NO
Coffeyville	13,970	NO
Chetopa	<2,500	NO
Baxter Springs	4,450	NO

Table 10. Population of Arkansas counties within eighty kilometer radius of Grand Lake.

County	1986 Population	Density	Total Sq. Mi.
Benton	89,000	105.6	843
Washington	107,400	112.9	951
Total Counties	196,400	109.5	1,794
Total State	2,372,000	45.5	52,078

% of State Pop. in counties = 8.2

Table 11. Population of Arkansas cities within eighty kilometer radius of Grand Lake.

City	1986 Population	MSA
Fayetteville	40,110	YES
Bentonville	10,960	NO
Rodgers	21,290	NO
Springdale	26,170	YES
Siloam Springs	8,450	NO
Gravette	<2,500	NO

Table 12. Population of Missouri counties within eighty kilometer radius of Grand Lake.

County	1986 Population	Density	Total Sq. Mi.
Newton	43,400	69.2	627
McDonald	15,900	29.4	540
Jasper	89,500	139.6	641
Total Counties	148,800	82.3	1,808
Total State	5,066,000	73.5	68,945

% of State Pop. in counties = 2.9

Table 13. Population of Missouri cities within eighty kilometer radius of Grand Lake.

City	1986 Population	MSA
Joplin	40,220	YES
Carthage	11,240	NO
Neosho	9,790	NO
Anderson	<2,500	NO
Webb City	7,250	NO
Seneca	<2,500	NO

Contribution of the Four States to Grand Lake Usage

In order to estimate the contribution of each of the states to Grand Lake usage the following method is utilized. The procedure is based on information of respondent origin taken from the Oklahoma Department of Tourism and Recreation, Park Visitor Survey, 1987. The number of state park users from each state is estimated by identifying the Zip Code reported by respondents, from state parks on Grand Lake only, and extrapolating the actual number and percentage of individuals visiting a state park site proportional to the visitation figures for the year 1987. Table 14 identifies the relative contribution of lake usage (for state park access for those state parks on Grand Lake only) for each of the four states.

It should be noted that origins of visitors are not limited to the eighty kilometer radius and the extrapolated totals are estimates based on a randomly selected population of respondents. In addition the number of state park users is a small percentage of overall lake usage which must be greater than these figures represent. Even with these caveats the estimated contribution of persons from each state to state park usage is relevant.

Table 14. State origins of Grand Lake state park users in 1987.

State	# of Visitors From Survey	% of Total Visitors	Extrapolated Total
Kansas	4	2.86	22864
Missouri	3	2.14	17108
Arkansas	11	7.86	62838
Oklahoma	116	82.86	662440
Other	6	4.28	34217
Total	140	100.00	799467

Total visitors to state parks on Grand Lake, 1987: 799,470.
Extrapolated total does not add to 100% due to rounding.

Taking into consideration the of state of origin allows for extrapolation to the relative contribution of each state to the use of Grand Lake (for state parks only). Even though this data is for state parks only it can lead to a better understanding of the contribution that each state adds to total lake usage by providing hard data on visitor origins.

Based on this comparison the state with the largest contribution of visitors is Oklahoma, with 662,440 persons per year. This is not surprising due to the location of the lake and its notoriety within Oklahoma. This finding is in agreement with the overall state park usage reported by the Oklahoma Tourism and Recreation Department of eighty percent usage by Oklahoman's. The second state in level of contribution is Arkansas, with an estimated 62,838 persons per year, third in contribution is Kansas, with an estimated 22,864 persons per year, fourth in contribution is Missouri, with an estimated 17,108 persons per year. Oklahoma's contribution is greatest, however the number of persons coming from Arkansas is important to overall usage. This may be due to the proximity of Grand Lake to the northeast corner of Arkansas, which has a relatively high density and a large population of retirees.

Discussion

The total population within the eighty kilometer radius of Grand Lake is 612,510. This population represents the hypothetical population of lake users, however just beyond this radius lie several additional population centers that contribute to the use of Grand Lake. Examples include: Wichita, KS; Fort Smith, AR; Tulsa, OK; Oklahoma City, OK; and Springfield, MO. These centers are within three to five hours driving time and could contribute significantly to increased lake usage. Several of these centers contribute at this time, however the relative contribution of each one can not be documented with limited data. It is probable that with improved lake quality increased contributions to usage from each of these areas could be expected.

Population characteristics of the four county region

The population characteristics of the four county region, by county, within which Grand Lake is formed are presented. This information provides increased detail of the socioeconomic characteristics of these counties which make up the shore line of Grand Lake and adjacent area. Various data sources are combined to construct tables of the socioeconomic characteristics of the four county region, by county, within which Grand Lake is formed. Refer to Task 4, Figure 6 for spatial reference.

Sources:

1980 Population: U.S. Bureau of the Census, 1980 Summary Tape File A.

1950-1970 Population: U.S. Bureau of the Census, General Characteristics of the Population.

1990-2000 Population: Center for Economic and Management Research, University of Oklahoma, Statistical Abstract of Oklahoma 1980, pp. 20-23.

Acres of Land/Water: Oklahoma Soil Conservation Service, "Oklahoma Land Inventory," January 1978.

Square Miles: U.S. Bureau of Census, Geography Division, Computer Graphic Staff, 1980.

U.S. Bureau of the Census, 1964, 1968, 1974, 1978 Census of Agriculture.

Oklahoma Soil Conservation Service, "Oklahoma Conservation Needs Inventory," March, 1970, p. 11; and "Oklahoma Land Inventory," January 1978, p. 5.

1950, 1960, 1970 data: U.S. Bureau of the Census, General Social and Economic Characteristics.

1950-1960 Per Capita Income: Bureau of Business and Economic Research, University of Oklahoma, "County Personal Income in Oklahoma," Appendix B, Table B-4.

1970, 1979 Per Capita Income: Bureau of Economic Analysis, "Per Capita Personal Income in Counties in Selected Years."

1950-1970 Median Family Income: U.S. Bureau of the Census, Census of Population, General Social And Economic Characteristics.

1950-1970 Labor Force: U.S. Bureau of Census, General Social and Economic Characteristics. 1980 Labor Force: Oklahoma Employment Security Commission, "1980 Preliminary Labor Force Data."

1970 Participation Rates: Oklahoma Employment Security Commission, "Manpower Information For Affirmative Action Programs."

Bureau of Economic Analysis, "Employment by Type and Broad Industrial Sources 1973-1979," (table 25.00)

Pre-1972 Data: Peach, W. Nelson, Richard W. Pole, and James D. Tarver, Oklahoma state University Research Foundation, "County Building Block Data for Regional Analysis-Oklahoma," March 1965.

1972, 1977 Data: U.S. Bureau of Census, Census of Retail Trade.

County Profile: Craig

General Information

SMSA : Non-SMSA County

Largest City : Vinita 1980 Population : 6,740

Acres of Land : 488,331 Acres of Water : 629

Total Acres : 488,960 Square Miles : 763

Population

	Population	Population Change	Density	Percent Urban
1950	18,263	------	23.9	30.2
1960	16,303	-1,960	21.4	37.0
1970	14,722	-1,581	19.3	39.7
1980	15.014	292	19.7	44.9
1990- Projected				
	14,600	-414	19.1	----
2000-Projected				
	14,400	-200	18.9	----

Agriculture

	1964	1969	1974	1978
Number of Farms	1,324	1,255	1,049	1,117
Avg. Acres/Farm	326	340	378	357
Percent of Land Devoted to Farms				
	88.30	87.30	81.10	81.60
Avg. Value/Farm	$34,949	$54,820	$118,513	$33,349
Irrigated Acres	181	4	---	532
Farms With Sales > $20,000				
	81	131	160	263
Market Value of All Ag. Products Sold in 000's				
	$9,744	$15,739	$22,203	$33,349

County Profile: Craig
(continued)

Land Use

	Cropland	Pastureland	Rangeland	Forestland
1958	190,790	7,154	222,364	46,207
1967	133,492	94,279	210,973	25,285
1978	61,425	200,208	153,141	27,690

Per Capita and Median Family Income

	Per Capita Income	Median Family Income
1950	$591	$1,510
1960	$1,276	$3,691
1970	$2,157	$6,215
1980	$8,933	N/A

Labor Force

	Total Labor Force	Employed	Unemployed	Unemployment Rate
1950	5,586	5,440	146	2.61
1960	5,162	4,937	225	4.36
1970	5,244	5,096	148	2.82
1980	7,200	6,860	340	4.72

County Profile: Craig
(continued)

Employment Data

	1973	1976	1979
Total Wage & Salary Employment	5,074	5,377	5,217
Farm	153	183	173
Non- Farm	4,921	5,194	4,954
Private	2,479	2,603	3,157
Government	2,442	2,591	1,797

Private Sector Employment

	1973	1976	1979
Ag. Serv., Forest, Fisheries	-----	25	32
Mining	-----	350	532
Construction	56	57	72
Manufacturing	639	372	528
Transportation	308	324	368
Wholesale Trade	23	194	202
Retail Trade	693	677	764
Fin., Insur., Real Estate	112	126	150

Government Employment

	1973	1976	1979
Fed.,Civilian	78	60	67
Fed.,Military	98	86	84
State and Local	2,266	2,445	1,646

County Profile: Ottawa

General Information

SMSA : Non-SMSA County

Largest City : Miami 1980 Population : 14,237

Acres of Land : 296,651 Acres of Water : 12,496

Total Acres : 309,120 Square Miles : 484

Population

	Population	Population Change	Density	Percent Urban
1950	32,218	-----	66.6	48.9
1960	28,301	-3,917	58.5	54.5
1970	29,800	1,499	61.6	55.3
1980	32,870	3,070	67.9	51.1
1990-Project.	34,600	1,730	71.5	-----
2000-Project.	36,500	1,900	75.4	-----

Agriculture

	1960	1969	1974	1978
Number of Farms	990	1,041	835	927
Avg. Acres/Farm	211	221	254	237
% Land Devoted to Farms	70.90	77.50	71.50	74.00
Avg. Value/Farm	$31,732	$45,126	$93,255	$141,374
Irrigated Acres	193	198	222	226
Farms with Sales >$20,000	37	76	151	192
Market Value of All Ag. Products Sold in 000's	$4,593	$6,869	$13,314	$18,225

County Profile: Ottawa
(continued)

Land Use

	Cropland	Pastureland	Rangeland	Forestland
1958	118,564	9,949	60,312	82,953
1967	102,443	64,680	28,406	78,400
1978	66,942	128,497	58,159	13,211

Per Capita and Median Family Income

	Per Capita Income	Median Family Income
1950	$1,044	$2,326
1960	$1,569	$4,120
1970	$2,482	$7,264
1980	$8,975	N/A

Labor Force

	Total Labor Force	Employed	Unemployed	Unemployment Rate
1950	10,916	10,069	847	7.76
1960	9,368	8,797	571	6.10
1970	11,394	10,831	563	4.94
1980	13,300	12,075	1,225	9.21

County Profile: Ottawa (continued)

Employment Data

	1973	1976	1979
Total Wage & Salary Employment	9,574	9,795	11,546
Farm	205	263	249
Non-Farm	9,369	9,532	11,297
Private	7,516	7,538	9,282
Government	1,853	1,994	2,015

Private Sector Employment

	1973	1976	1979
Ag. Serv., Forest, Fisheries	35	24	30
Mining	59	78	62
Construction	286	246	243
Manufacturing	3,640	3,269	4,599
Transportation	226	206	148
Wholesale Trade	207	358	386
Retail Trade	1,421	1,453	1,634
Fin., Insur., Real Estate	288	282	323

Government Employment

	1973	1976	1979
Fed., Civilian	192	199	231
Fed., Military	217	201	185
State and Local	1,444	1,594	1,599

County Profile: Delaware

General Information

SMSA : Non-SMSA County

Largest City : Grove 1980 Population : 3,378

Acres of Land : 451,483 Acres of Water : 47,077

Total Acres : 498,560 Square Miles : 792

Population

	Population	Population Change	Density	Percent Urban
1950	14,734	-----	18.6	0.0
1960	13,198	-1,536	16.7	0.0
1970	17,767	4,569	22.4	0.0
1980	23,946	6,179	30.2	14.1
1990-Project.	23,900	-46	30.2	-----
2000-Project.	26,400	2,500	33.3	-----

Agriculture

	1964	1969	1974	1978
Number of Farms	1,422	1,165	1,011	1,170
Avg. Acres/Farm	184	223	234	245
% Land Devoted to Farms	57.40	57.50	52.30	63.30
Avg. Value/Farm	$22,151	$40,691	$83,099	$147,513
Irrigated Acres	448	527	156	132
Farms with Sales >$20,000	73	131	155	248
Market Value of All Ag. Products Sold in 000's	$6,496	$11,256	$16,147	$26,809

County Profile: Delaware

(continued)

Land Use

	Cropland	Pastureland	Rangeland	Forestland
1958	98,887	432	53,278	291,350
1967	63,512	60,695	62,772	254,200
1978	12,698	220,824	7,473	182,732

Per Capita and Median Family Income

	Per Capita Income	Median Family Income
1950	$322	$1,108
1960	$727	$2,352
1970	$1,867	$4,398
1980	$5,001	N/A

Labor Force

	Total Labor Force	Employed	Unemployed	Unemployment Rate
1950	4,323	4,182	147	3.26
1960	3,634	3,435	199	5.48
1970	4,983	4,761	222	4.46
1980	9,850	9,210	640	6.50

Employment Data

	1973	1976	1979
Total Wage & Salary Employment	2,681	3,177	4,009
Farm	160	188	179
Non-Farm	2,521	2,989	3,830
Private	1,670	2,053	2,887
Government	851	936	943

Private Sector Employment

	1973	1976	1979
Ag. Serv., Forest, Fisheries	26	28	34
Mining	0	0	0
Construction	131	158	446
Manufacturing	296	408	481
Transportation	55	65	77
Wholesale Trade	47	58	108
Retail Trade	397	466	600
Fin., Insur., Real Estate	63	105	186

Government Employment

	1973	1976	1979
Fed., Civilian	60	70	76
Fed., Military	130	122	117
State and Local	661	744	750

County Profile: Mayes

General Information

SMSA : Non-SMSA County

Largest City : Pryor Creek 1980 Population : 8,483

Acres of Land : 393,978 Acres of Water : 46,342

Total Acres : 440,320 Square Miles : 683

Population

	Population	Population Change	Density	Percent Urban
1950	19,743	-----	28.9	22.7
1960	20,073	330	29.4	32.3
1970	23,302	3,229	34.1	30.3
1980	32,261	8,959	47.2	26.3
1990-Project.	40,500	8,239	59.3	-----
2000-Project.	55,300	14,800	81.0	-----

Agriculture

	1964	1969	1974	1978
Number of Farms	1,433	1,247	1,103	1,258
Avg. Acres/Farm	211	225	221	222
% Land Devoted to Farms	70.00	67.80	58.70	67.10
Avg. Value/Farm	$28,453	$47,237	$86,974	$152,673
Irrigated Acres	310	98	58	232
Farms with Sales >$20,000	47	104	123	211
Market Value of All Ag. Products Sold in 000's	$5,705	$8,876	$10,365	$19,112

County Profile: Mayes
(continued)

Land Use

	Cropland	Pastureland	Rangeland	Forestland
1958	134,334	29,784	81,997	113,805
1967	65,536	115,705	75,665	112,800
1978	25,309	195,785	44,359	80,177

Per Capita and Median Family Income

	Per Capita Income	Median Family Income
1950	$501	$1,511
1960	$1,160	$3,468
1970	$2,184	$6,255
1980	$7,228	N/A

Labor Force

	Total Labor Force	Employed	Unemployed	Unemployment Rate
1950	6,147	5,831	316	5.14
1960	6,139	5,757	382	6.22
1970	7,807	7,326	481	6.16
1980	15,640	14,570	1,070	6.84

Employment Data

	1973	1976	1979
Total Wage & Salary Employment	6,007	7,533	8,254
Farm	131	156	147
Non-Farm	5,876	7,377	8,107
Private	4,294	5,628	6,445
Government	1,582	1,749	1,662

Private Sector Employment

	1973	1976	1979
Ag. Serv., Forest, Fisheries	62	--	--
Mining	--	14	--
Construction	232	390	730
Manufacturing	1,854	2,569	2,575
Transportation	179	192	208
Wholesale Trade	--	141	--
Retail Trade	921	1,145	1,354
Fin., Insur., Real Estate	130	--	--

Government Employment

	1973	1976	1979
Fed., Civilian	70	69	90
Fed., Military	170	169	160
State and Local	1,342	1,511	1,412

Discussion

Based on the average of seventy-one percent of land in the four counties being devoted to farming interests, it is possible to classify these counties as agricultural in type. However the importance of agricultural output of these counties varies due to several factors, such as: (1) acres of range/pasture/crops to acres of water; and (2) whether there is an urban center in the county that contributes to manufacturing as an employment source.

The yearly per capita incomes of Craig ($8,933) and Ottawa ($8,975) counties are both considerably higher than Mayes ($7,228) or Delaware ($5,001) per capita income levels. Output of farms seems to be important to these totals. For example in 1978, Mayes county produced $19,112,000 in sales from 1,258 farms and Delaware county $26,809,000 from 1,170 farms, compared to Craig county with $33,349,000 from 1,117 farms and Ottawa county with $18,225,000 from 927 farms. These ratios, excluding Ottawa, which is dominated by an urban center, (i.e, Miami) show the reliance of the economies of Delaware and Mayes counties on tourism. Neither have any significant industry and both counties have close connections with large lakes, Delaware and Grand Lake, Mayes and Lake Hudson, these relationships seem to be important contributors to the overall economic well being of these counties. For example, Delaware county employed 481 individuals out of a total labor force of 9,850 in manufacturing, while Ottawa employed 4,599 out of 13,300. The difference seems to be due to the urban center located in Ottawa county. It should be noted that many individuals do commute to work from sites outside of Delaware county.

To provide background for the current situation, a brief explanation of the history of the farmland in Mayes and Delaware counties is appropriate. In both cases, but primarily Delaware county, when the lakes were constructed considerable amounts of excellent bottomland were flooded, this created a lack of desirable cropland. The prime farmland that remained was already owned, consequently many farm families did not continue farming or moved to land that was much less productive. Those individuals with foresight, or aggressiveness, purchased land that seemed of little value at the time, but would become the shorelines of these lakes. Eventually these properties would have great value and these individuals knew this. This was one way wealth in the counties became concentrated in the hands of a few.

The per capita income levels of Delaware county are low, and have been traditionally, since subsistence farming was the norm in this county for many years. The Indian population adapted to this lifestyle after being moved into the area, circa 1890, and still maintains it in the southern half of the county. If the county were bisected in half at the southern end of Grand Lake, Kenwood Indian Reserve would make up a large part of this extremely rural area. The north half would contain Grand Lake and the population centers associated with the lake, (i.e., Grove). Business from tourism would dominate this half of the county while agricultural interests would dominate the southern half of the county. Without the lake as a source of income generation the county would indeed be one of the poorest in the state, if not the poorest per capita.

Today there are distinct strata identified by residents of Delaware county that are related to the lake, these are: (1) hollow people, those living on poor farmland, primarily Indian and poor; (2) hill people, ranchers and farmers with large operations, predominantly white; and (3) lake people, those people drawn to the county because of business opportunities.

The location of Grand Lake is an enigma because of the hardship it caused at its creation and because of its necessity to the continued prosperity of Delaware county, which contains eighty percent of its volume. Due to this situation it must be protected as a resource that contributes enormously to the well being of many individuals.

OUTPUT 6: Historical Lake Use

OBJECTIVE: Statistical summary of historical use of the lake and how this use may have changed due to changes in aesthetics and water quality.

DISCUSSION: Grand Lake was formed in 1940 by damming the Grand River. Project purposes are hydroelectric power generation, flood control, and recreation. Grand Lake has provided residents of Oklahoma and surrounding states excellent fishing, boating, and picnicking activities for many years. Hopefully, water quality can be maintained or improved in order to enhance these recreational opportunities for many more years.

Sources:

Heritage of the Hills. 1979. Grove, OK: Delaware County Historical Society.

United States Bureau of the Census. 1960. Census of population and housing characteristics: Summary population and housing characteristics. CPH-1-38, Oklahoma.

United States Bureau of the Census. 1970. Census of population and housing characteristics: Summary population and housing characteristics. CPH-1-38, Oklahoma.

United States Bureau of the Census. 1980. Census of population and housing characteristics: Summary population and housing characteristics. CPH-1-38, Oklahoma.

United States Bureau of the Census. 1990. Census of population and housing characteristics: Summary population and housing characteristics. CPH-1-38, Oklahoma.

This section of Task 6 will address the historical development of Grand Lake as a tourist attraction. The focus will be on the history and the population characteristics of Delaware County.

Delaware County History

The Delaware County region was not occupied by large numbers of Native Americans around 1800, the time of the Louisiana Purchase. The Osage Tribe was the only tribe to use the area and they used it primarily for hunting. In 1825 the Osage signed treaties allowing the inclusion, within the area, of several tribes from other parts of the country. One such group was part of the Delaware Tribe that moved to the south side of Spavinaw Creek near Eucha (pronounced Uchee by the locals). The county takes its name from the group's settlement, "Delaware Towne", which was located at that spot around 1830. The two major tribes relocated to Delaware County were the Cherokees and the Seneca-Cayuga. What was to become Delaware County was at that time part of the National Council's eight districts established in 1840. The Cherokee Tribe was settled in the southern part of the county from the town of Grove south. To the north, the Seneca-Cayuga Tribes were resettled in the northeastern section of the region from about two miles north of the town of Grove and between the Missouri state line on the east and the Grand River on the west. The Seneca Tribe was resettled from Sandusky, Ohio, in the spring of 1831 (Heritage of the Hills, 1979). To this day the only significant ethnic group in Delaware County is the Native American population. The county population is dominated by whites as will become evident in following section.

Delaware County Population Characteristics

The racial characteristics of the population of Delaware County are very homogeneous. In 1990 the predominate racial group was white seventy-four percent, followed by American Indian twenty-five percent, with several other racial groups being insignificant in representation. The most salient feature is the relative non-existence of blacks in the population. Table 15 shows the 1990 racial characteristics of the population. It is important to note the homogeneity of the population.

Table 15. Racial Characteristics of Delaware County, 1990

Race	Number	Percent
White	20,848	74
Native American	7,096	25
Black	20	-
Asian, Pacific Is.	43	-
Other	63	-

Note. - equals insignificant percentages. From 1990 U.S. Census, Summary of Population and Housing.

Delaware County did not contain an urbanized area until the 1980 census. Urbanized areas are defined by the United States Census Bureau as any place with 2,500 or more persons residing within its boundaries. Information on the Rural/Urban breakdown of Delaware County population for the census periods 1960-1990 is presented in Table 16.

Based on this information it is obvious that the overall population distribution of Delaware County is dominated by its rural characteristics. The town of Grove is the only urban place. It has had an important influence on the growth of the Grand Lake area as a tourist attraction. In the thirty years between the 1960 and the 1990 censuses, the total population of Delaware

Table 16. Delaware County by Urban/Rural Residence

Year	Urban	Rural
1960	non-urbanized area	13,198
1970	non-urbanized area	17,767
1980	3,378 (Grove town)	20,568
1990	4,020 (Grove town)	24,050

Note. From United States Bureau of the Census, 1960-1990, Summary of Population Characteristics.

County increased by 14,872 persons as shown in Table 17. This increase is 113 percent over a thirty year period. This increase in population is not simply the result of natural increase, but is heavily influenced by the migration of large numbers people to Delaware County.

Table 17. Population Trends by Decade for Delaware County

Year	1960	1970	1980	1990
Total Population	13,198	17,767	23,946	28,070

Note. From United States Bureau of the Census, 1960-1990, Summary of Population Characteristics.

In the thirty years between the 1960 and the 1990 censuses, the population subdivision changes in Delaware County reflect the disproportionate increase of the Grove subdivision. The population changes by subdivisions of Delaware County are shown in Table 18. Table 18 indicates the population growth of Grove relative to other Delaware County subdivisions. Table 19 indicates projected growth for the Grand Lake area. These changes are of significant consequence to the Grove area. Such increases in population bring simultaneous changes in social and economic organization. These changes become evident when comparing social and economic structures, which are much more extensive and complex, in the Grove area with other areas in Delaware County that are not as heavily influenced by the lake.

Discussion

The data presented in this task show conclusively that Grand Lake has had a major impact on the growth of the region. Without the attraction of Grand Lake the region would not have grown as it has and would not be the thriving area it is today.

Table 18. Population Trends in Delaware County Subdivisions.

	Year of Census			
Subdivision	1960	1970	1980	1990
Colcord Div.	-	-	3639	4207
Colcord town	173	438	530	628
West Siloam Sp.	-	210	431	539
Grove Div.	-	-	9642	12489
Bernice town	100	189	318	330
Grove town	975	2000	3378	4020
Jay Div.	-	-	6897	7400
Jay town	1120	1594	2100	2220
Kansas Div.	-	-	3768	3974
Kansas town	-	317	491	556
Oaks town	-	219	591	398

Note. - equals data unavailable. From United States Bureau of the Census, 1960-1990, Summary of Population Characteristics.

Table 19. Selected Characteristics of Thirteen Grand Lake Communities

City/Town	1980 Population	2000 Projections	2030 Projections	Median Age	Age Male	Age Female
Afton	1174	1250	1150	36.6	34.3	38.8
Bernice	318	800	2600	54.8	55.6	53.5
Disney	464	800	1550	50.1	50.9	49.5
Fairland	1073	1550	2200	N/A	N/A	N/A
Grove	3378	5200	7900	48.3	45.4	50.6
Jay	2100	3400	5800	35	31.6	36.0
Ketchum	326	400	400	33	31.2	36.0
Langley	582	1300	3300	41.1	39.6	42.7
Miami	14237	17700	19900	32.2	29.0	35.6
North Miami	544	650	700	29.5	28.2	30.9
Vinita	6740	8000	8400	39.4	34.9	43.4
Wyandotte	336	450	500	31.6	29.4	33.0
Grand Lake Towne	36	50	50	55.0	55.0	55.0

TASK 7: Population Affected by Lake Degradation

OBJECTIVE: To describe the extent to which the population connected with the lake would experience a negative impact if further lake degradation occurred. Including the location, characteristics and size of the population at risk.

RESPONSIBILITY: OWRB and OSU

METHODS: Census

Chambers of Commerce

Interviews with lake users and residents

Consultation with GRDA Lake Patrol

Consultation with Grand Lake Association

Consultation with Oklahoma Tourism and Recreation Department

North East Counties of Oklahoma Economic Development Association

1980 United States Census

Information and Research Division, Oklahoma Department of Commerce

United States Travel Data Center

DISCUSSION: Economic Summary of the Grand Lake Region

Socioeconomic Characteristics of Communities Around Grand Lake

There are thirteen communities that are directly connected to Grand Lake by it's domination of their respective economic and social structures. These communities gain substantial portions of their livelihood from the various benefits provided by their proximity to Grand Lake. The following summaries of the characteristics of these thirteen communities should provide insight into the extent of this interdependence. Please refer to Task 4, Figure 6 for spatial locations of the selected communities.

Community Profiles:

Community Profile: Afton, OK

County: Ottawa Population: 1,174 (1980)

City sales tax: .03 Education: K-12 Enrollment: 800, Northeast OK Vo-tech

Transportation: Burlington Northern freight. No airport or bus service.

Health Care: One clinic, one doctor.

Largest Employer: Farmland Industries

Number of Employees: 30-60

Lodging: Rogers Motel, Rest Haven Motel, Grand Lake Country Inn

Utilities:

Electric: Public Service Co. of OK Base rate: .070 KWH

Gas: City Owned Base rate: $5.00

Water: City Owned, from Grand Lake Base rate: $6.00 M.G.

Sewer: City Owned Base rate: $7.50 M.G.

Sanitation: Sunrise Sanitation Base rate: $4.50

Telephone: Southwestern Bell and AT&T

Community Profile: Bernice, OK

County: Delaware Population: 318 (1980)

City sales tax: .02 Education: Buses to Cleora or Afton, Grove High School

Largest Employer: Jerry's Dock Construction

Number of Employees: N/A

Lodging: Indian Hills Resort, RV Parks, Mobile Home Rental Parks

Utilities:

Electric: Public Service Co. of OK Base rate: .070 KWH

Gas: Propane only

Water: Bernice Public Works Well Base rate: $10.50 M.G. water, 1400', chlorinated 86,000 gal. storage

Sewer: Septic Tanks

Telephone: Southwestern Bell and AT&T

Community Profile: Disney, OK

County: Mayes Population: 464 (1980)

City sales tax: .03 Education: Bus to Jay schools

Health Care: One mile to Langley doctor

Largest Employer: Disney Dandy

Number of Employees: 8

Lodging: Rodgers Cabins

Utilities:

Electric: Northeast OK Elec. Coop. Base rate: .0575 KWH, $8.75 Min.

Gas: Propane only

Water: Rural Water District #3 Base rate: $12.00 first 2000 gal.

Sewer: Septic tanks

Sanitation: F & F Refuse

Telephone: Grand Telephone Company

Other: 30 retail Businesses employ 80 individuals with retail sales of $2,000,000 annually.

Community Profile: Fairland, OK

County: Ottawa Population: 1,150 (1980)

City sales tax: .03 Education: K-12

Transportation: Burlington Northern freight. Can flag Trailways bus.

Largest Employer: Fairland Lumber

Lodging: Maverick Motel, Stardust Motel

Utilities:

Electric: Empire Electric Co.

Gas: Northeast OK Utilities

Water: City Owned, two wells Base rate: $6.50 min. to 2000 gals.

Sewer: City Owned, Lagoon system Base rate: $2.00 min., $.39 per 1,000

Sanitation: Sunrise Sanitation Base rate: $4.50

Telephone: Southwestern Bell and AT&T

Community Profile: Grove, OK

County: Delaware Population: 4,200 (1980)

City sales tax: .03 Education: K-5 Enrollment: 716, 6-8: 307, 9-12: 520

Transportation: Grove Municipal Airport: 3400' paved/lighted runway with rotating beacon; Taxi service; Jones Truck Lines, UPS, Yellow Freight, Okmulgee Express

Hospital: Grove General Hospital (full service) 59 beds

Health Care: two nursing homes: Grand Lake Manor and BettyAnn Nursing Home with 160 beds total one retirement center with assisted living: Honey Creek Retirement Village ten MD's, four DDS, two optometrists, one opthamologist, one podiatrist, three chiropractors

Largest Employer:	Number of Employees
Grove School System	169
Grove General Hospital	150
Wal-Mart	127
Precision Machine	63
McDonald's	70

Lodging: Six Motels, Several Cabin Resorts, Several RV Parks

Utilities:

Electric: Public Service Co. of OK Base rate: .070 KWH

Northeast OK Elec. Coop .0575 KWH, $8.75 Min.

Gas: Northeast OK Public Facility Authority Base rate: $4.00 Min. per 100 CF + cost adj.

Water: Grove Municipal Services Authority Base rate: $3.50/2MG in city $7.50/2MG out of city

Sewer: Grove Municipal Services Authority Base rate: $2.50/2MG extended aeration

Sanitation: Roberts Sanitation Base rate: $5.00 per month

Billing: Grove Municipal Services Authority

Telephone: Southwestern Bell and AT&T

Other: 366 retail businesses with annual retail sales of $51,138,527.

Community Profile: Jay, OK

County: Delaware Population: 2,540 (1980)

City sales tax: .03 Education: K-12 Enrollment: 1500

Transportation: UPS.

Health Care: Cherokee Nation Indian Clinic.

Largest Employer: Simmons Industries, Government Offices, County Courthouse

Lodging: Holiday Pines Motel

Utilities:

Electric: Public Service Co. of OK Base rate: .070 KWH

Gas: NEO Public Facilities Auth. Base rate: $4.62 1st MCF + cost Adj.

Water: Jay Utilities Auth. (City of Tulsa Plant) Base rate: $6.20 1st. 2M gallons

Sewer: Lagoons

Sanitation: Sunrise Sanitation Base rate: $4.50

Telephone: Grand Telephone Company

Other: Delaware county seat.

Community Profile: Ketchum, OK

County: Craig Population: 350 (1980)

City sales tax: .02.25 Education: K-12

Health Care: Dr. Arthur Hoge's Family Clinic.

Largest Employer: Ketchum Schools

Lodging: Grand Lodge Motel

Utilities:

Electric: Public Service Co. of OK Base rate: .070 KWH

Northeast OK Elec. Coop .0575 KWH, $8.75 Min.

Water: Ketchum Public Works (from Grand Lake) Base rate:$10.00 in city

$14.00 old/out; $18.00 new/out 1st M Gallons

Sewer: Ketchum Public works Base rate: $7.00; currently activated sludge getting lagoon)

Sanitation: F and F Refuse

Telephone: Southwestern Bell and AT&T

Other: 30 retail businesses with 65 employees.

Community Profile: Langley, OK

County: Mayes Population: 582 (1980)

City sales tax: .03 Education: Ketchum Public Schools

Health Care: Dr. Ralph Dru, MD

Largest Employer: Reasor's Grocery # of Employees: 33; Dick's Grill

Lodging: Cliff-Pat Motel, Cherokee Motel, Lifted-Up Motel

Utilities:

Electric: Public Service Co. of OK Base rate: .070 KWH

Northeast OK Elec. Coop .0575 KWH, $8.75 Min.

Water: City Owned; Base rate:$7.00 in city, $9.00 out of city, 1st M Gallons

Sewer: Filtration/oxidation/lagoon Base rate: $9.11 1st MG + .06 per M

Sanitation: F and F Refuse

Telephone: Southwestern Bell and AT&T

Community Profile: Miami, OK

County: Ottawa Population: 15,100 (1980)

City sales tax: .03 Education: K-12, Northeast OK A&M, 2 year Junior College

Hospital: Baptist Regional Hospital (full service) 134 beds.

Health Care: 3 Clinics, 1 Indian Clinic, 23 MD's, 5 DO's, 11 DDS, 5 Optometrists, 3 Chiropractors, 3 Nursing Homes

Transportation: Trailways and Greyhound Bus service; Burlington Northern Freight switching; UPS and Federal Express.

Largest Employer: Number of Employees:

NEO A&M College

Baptist Reg. Hosp. Total over 900

Bayliner Boats

Lodging: Continental Motel, Townsman Motel, Thunderbird Motel, Super 8 Motel

Utilities:

Electric: City Owned, Purchased from GRDA

Gas: KPL Gas Service

Water: City Owned, Deep wells drawn from Roubidoux aquifer Base rate: $1.10/M 1st 11 M Gallons

Sewer: Activated sludge system with Base rate: $1.65 MG; 2 extended aeration. 1.5 mgd Capacity

Sanitation: City owned. Base rate: $6.00 residential min.

Telephone: Southwestern Bell and AT&T

Other: 195 retail businesses with over 1252 employees and $73,559,000 in retail sales annually.

Community Profile: Vinita, OK

County: Craig Population: 6,740 (1980)

City sales tax: .02 Education: K-12, enrollment 1518.

Hospital: Craig General Hospital, 134 beds.

Health Care: 4 MD's, 1 DO, 4 DDS, 3 Optometrists, 1 Chiropractor, 3 Nursing Homes: 277 beds, 2 clinics, Eastern State Mental Hospital

Transportation: Trailways and Greyhound Bus service, Burlington Northern Freight switching, UPS and Federal Express.

Largest Employer: Cinch Manufacturing, Dana Manufacturing

Lodging: Rodeo Motel, Lewis Motel, Holiday Motel, Deward and Pauline Motel, Park Hills Motel, Western Motel

Utilities:

Electric: Public Service Co. (PSO) Base rate: .075 KWH

Gas: KPL Gas Service

Water: City Owned, from Grand Lake, purified, Base rate: $4.90 1st 2 M Gallons

Sewer: Activated sludge system Base rate: $2.34 1st 2MG + .67 per M

Sanitation: City owned. Base rate: $5.00

Telephone: Southwestern Bell and AT&T

Based on the community profiles of these thirteen towns and cities located on or near Grand Lake's shore it is evident that without the lake as a source of attraction to the area many of these communities would have significant problems maintaining their current service and population levels.

Routes and Distances From Major Population Centers

The Grand Lake geographical area is known as the Four State Region, (i.e., Kansas, Missouri, Arkansas and Oklahoma), and is within short road trips of several large metropolitan areas. Please refer to Task 4, Figure 5 and Figure 6 for spatial location and primary routes of travel to Grand Lake from these areas. The major population centers that are within five hours driving time are as follows: Wichita, KS, 204 miles; Kansas City, MO, 205 miles; Springfield, MO, 115 miles; miles; Tulsa, OK, 78, miles; Oklahoma City, OK, 184 miles; and Fort Smith, AR, 150 miles; These metropolitan areas contribute to overall usage of Grand Lake and should be considered when assessing impact. Several of these areas contribute substantially more to usage than others, but assessing the relative contribution with quantitative data is difficult. The following section estimates the contribution of the four surrounding states to the usage of Grand Lake.

Contribution of the Four States to Grand Lake Usage

In order to estimate the contribution of each of the states to Grand Lake usage the following method is utilized. The procedure is based on information of respondent origin taken from the Oklahoma Department of Tourism and Recreation, Park Visitor Survey, 1987. The number of state park users from each state is estimated by identifying the Zip Code reported by respondents, from state parks on Grand Lake only, and extrapolating the actual number and percentage of individuals visiting a state park site proportional to the visitation figures for the year 1987. Table 20 identifies the relative contribution of lake usage (for state park access for those state parks on Grand Lake only) for each of the four states.

Table 20. Origins of State Park Users by State for 1987 - Grand Lake Parks Only.

State	# of Visitors from Survey	% of Total Visitors	Extrapolated Total
Kansas	4	2.86	22,864
Missouri	3	2.14	17,108
Arkansas	11	7.86	62,838
Oklahoma	116	82.86	662,440
Other	6	4.28	34,217
Total	140	100.00	799,467*

Total visitors to state parks on Grand Lake, 1987: 799,470.
* Extrapolated total does not add to 100% due to rounding

It should be noted that origins of visitors are not limited to the eighty kilometer radius and the extrapolated totals are estimates based on a randomly selected population of respondents. In addition the number of state park users is a small percentage of overall lake usage which must be greater than these figures represent. Even with these caveats the estimated contribution of persons from each state to state park usage is relevant.

Taking into consideration the of state of origin allows for extrapolation to the relative contribution of each state to the use of Grand Lake (for state parks only). Even though this data is for state parks only it can lead to a better understanding of the contribution that each state adds to total lake usage by providing hard data on visitor origins.

Based on this comparison the state with the largest contribution of visitors is Oklahoma, with 662,440 persons per year. This is not surprising due to the location of the lake and its notoriety within Oklahoma. This finding is in agreement with the overall state park usage reported by the Oklahoma Tourism and Recreation Department of eighty percent usage by Oklahoman's. The second state in level of contribution is Arkansas, with an estimated 62,838 persons per year, third in contribution is Kansas, with an estimated 22,864 persons per year, fourth in contribution is Missouri, with an estimated 17,108 persons per year. Oklahoma's contribution is greatest, however the number of persons coming from Arkansas is important to overall usage. This may be due to the proximity of Grand Lake to the northeast corner of Arkansas, which has a relatively high density and a large population of retirees.

Cities and Towns Within the Eighty Kilometer Radius

When the eighty kilometer radius criteria is applied, the following cities and towns fall within the prescribed area: (miles represent distance to travel on highways) Joplin, MO, 45 mi.; Carthage, MO, 60 mi.; Neosho, MO, 35 mi.; Anderson, MO, 15 mi.; Webb City, MO, 50 mi.; Seneca, MO, 15 mi.; Fayetteville, AR, 75 mi.; Bentonville, AR, 50 mi.; Rodgers, AR, 60 mi.; Springdale, AR, 65 mi.; Siloam Springs, AR, 45 mi.; Gravette, AR, 40 mi.; Oswego, KS, 55 mi.; Columbus, KS, 45 mi.; Coffeyville, KS, 65 mi.; Chetopa, KS, 35 mi.; Baxter Springs, KS, 30 mi.; Miami, OK, 15 mi.; Vinita, OK, 20 mi.; Afton, OK, 10 mi.; Nowata, OK, 43 mi.; Claremore, OK, 45 mi.; Chouteau, OK, 40 mi.; Pryor, OK, 32 mi.; Tahlequah, OK, 55 mi.; Locust Grove, OK, 30 mi.

Please refer to Task 4, Figure 5 and Figure 6 for spatial location and primary routes of travel to Grand Lake from these areas. Selected population characteristics of the major population centers and towns/cities within the eighty kilometer radius of Grand Lake will be presented in the section dealing with population in the Grand Lake region.

Types and Geographic Location of Businesses Adjacent to Grand Lake

This section describes the types and number of businesses that are directly or indirectly related to Grand Lake. A brief description of the business facilities and location on Grand Lake are included.

Condominium Rental/Sales - There are six major condominium sales and rental locations on Grand Lake. They are located in the southern half of the lake, from Sailboat bridge, at Grove, OK to the Pensacola dam.

(1) Ballerina Pier 59 -Located north of Grove, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, camping, resale of boats, heated fishing dock and cottage/condo rentals and mobile home parking.

(2) Coves at Bird Island - Located southeast of Cleora, OK on Duck Creek with facilities for 24-hour security, paved roads, city water, tennis courts, swimming pools, boat slips, guest house, Golf Club, home sites and townhomes.

(3) Hi Point Condominiums - Located on Monkey Island with facilities for tennis courts, swimming pool, hot tub, fishing dock, boat slips and condo rental (fully equipped).

(4) Meghan Coves - Located south of Grove, OK with facilities for tennis courts, swimming pools, clubhouse, racquetball courts, fitness center, saunas, whirlpools, boat slips, fishing cottage, jogging and walking trails, sales and rentals of condos.

(5) Port Duncan - Located on Monkey Island with facilities for sale of condos, lots, houses, cottage rental, boat slips, full service marina, ships store and boat launching.

(6) Shangri-La - Monkey Island with facilities for Golf, fishing, boating, tennis courts, swimming pools, racquet ball courts, jogging trails, bowling, health spa and sales and rentals of condos, motel rooms, homes.

Campgrounds

There are nine major commercial campgrounds located at various places around Grand Lake. In addition there are several state parks that also provide camping opportunities. These are considered in task four.

(1) Ballerina Pier 59 - Located north of Grove, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, camping, resale of boats, heated fishing dock and cottage/condo rentals.

(2) Elk River Paradise - Located northeast of Grove, OK with facilities for Boat storage, full marine service, mobile home and RV park, convenience store, boat rental, boat launching, sale and resale of boats and motors, and camping.

(3) Four Seasons - Located northeast of Grove, OK with facilities for RV hook ups, boat launching, heated fishing dock, boat slips, swimming, laundry, convenience store, game room, boat rentals, rental cabins and camping.

(4) Fisherman's Paradise - Located northwest of Grove, OK with facilities for cabin rental, camping, RV hookups, boat launching, and personal hygiene.

(5) Gray's Ranch - Located north of Grove, OK with facilities for RV hookups, boat launching, camping and personal hygiene.

(6) Horse Creek Resort - Located east of Bernice, OK with facilities for cottage rental, RV hookups, boat launching, dry storage, convenience store and camping.

(7) King Point Resort - Located northeast of Grove, OK with facilities for mobile homes, cottage rental, boat and motor repairs, swimming, heated fishing dock, dry boat storage, RV hookups, boat launching, convenience store and camping.

(8) Lee's Resort - Located northeast of Grove, OK with facilities for mobile homes, RV hookups, cottage rental, boat launching, covered docks, boat rentals, heated fishing dock, swimming pool, tennis courts, playground, convenience store and camping.

(9) Red Rock Resort - Located north of Grove, OK with facilities for RV hookups, camping, convenience store, boat launching, enclosed fishing dock, slips, swimming pool and motel and cabin rental.

Commercial Marinas

There are thirty-two major commercial marinas operating on Grand Lake. The following is a discussion of the facilities available and location of each of these marinas.

(1) Anchor's End - Located south of Ketchum, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, heated fishing dock and cottage rentals.

(2) Arrowhead Yacht Club - Located east of Ketchum, OK with facilities for complete marine service, including sales and storage, and a full service marina.

(3) Ballerina Pier 59 - Located north of Grove, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, camping, resale of boats, heated fishing dock and cottage rentals.

(4) Barker's Edgewater Marine - Located northwest of Grove, OK with facilities for boat launching, swimming, mobile home rental, sale and resale of boats and motors.

(5) Blue Bluff Harbor - Located northeast of Grove, OK with facilities for mobile home lots, heated fishing dock, boat launching, wet boat storage and construction of docks.

(6) Cherokee Yacht Club - Located on Duck Creek, with full service country club environment, including swimming pool, tennis court, dining and party facilities and a full service marina.

(7) Coons Marine - Located north of Grove, OK with facilities for inside and outside boat storage, repairs, sales of new and used boats and motors and boat launching.

(8) Courthouse Marina - Located south of Grove, OK with facilities for boat rentals, boat launching, swimming, sale and resale of boats, heated fishing dock, cottage rentals, covered boat slips, full service dock and ski shop.

(9) Dick Lane Kawasaki-Yamaha, Port Carlos - Located east of Ketchum, OK with facilities for jet ski rental and boat launching.

(10) Elk River Marina - Located northeast of Grove, OK with facilities for sale and resale of boats and motors, repairs and boat launching.

(11) Elk River Paradise - Located northeast of Grove, OK with facilities for Boat storage, full marine service, mobile home and RV park, convenience store, boat rental, boat launching, sale and resale of boats and motors.

(12) Four Seasons - Located northeast of Grove, OK with facilities for RV hook ups, boat launching, heated fishing dock, boat slips, swimming, laundry, convenience store, game room, boat rentals and rental cabins.

(13) Grand Lake Charter and Rentals - Located on Honey Creek State Park, Grove, OK with facilities for boat launching, charter service and boat rentals.

(14) Harbors View Marina - Located southeast of Cleora, OK with facilities for boat and motor sales and repair, full service marina and boat launching.

(15) Hi-Lift Marina - Located east of Disney, OK with facilities for dry dock storage, covered slips, ships store, sales, service and full service marina.

(16) Hills Resort - Located south of Grove, OK with facilities for cottage rental, swimming, boat and motor rental, covered dock, wet and dry dock, boat launching, convenience store, fishing guide service and heated fishing dock.

(17) Honey Creek Resort - Located on south Main St. Grove, OK with facilities for cottage rentals, boat dock, boat launching, swimming, enclosed fishing dock, fishing pier, boat rentals, fishing guide, motel and airport pick-up.

(18) Indian Hills Resort - Located in Bernice, OK with facilities for cottage rental, swimming, boat launching, heated fishing dock, convenience store, full service marina, boat and motor rental, RV hookups and snack bar.

(19) Jerry's Marina and Storage - Located in Bernice, OK with facilities for lift repair, barge service, dock construction, boat sales, wet slips, dry storage and boat launching.

(20) King Point Resort - Located northeast of Grove, OK with facilities for mobile homes, cottage rental, boat and motor repairs, swimming, heated fishing dock, dry boat storage, RV hookups, boat launching and convenience store.

(21) Lee's Resort - Located northeast of Grove, OK with facilities for mobile homes, RV hookups, cottage rental, boat launching, covered docks,

boat rentals, heated fishing dock, swimming pool, tennis courts, playground and convenience store.

(22) Long's Resort - Located west of Grove, OK with facilities for cottage rental, boat launching, heated fishing dock, boat slips and convenience store.

(23) Monkey Island East Bay - Located on Monkey Island with facilities for cottage rentals, mobile homes, slips, full service marina and boat launching.

(24) Out of the Ordinary at Pier III - Located south of Grove, OK with facilities for cottage rental, boat rental, ships store, covered boat slips, restaurant, full service marina and boat launching.

(25) Pla-Port Resort - Located in Grove, OK with facilities for mobile homes, swimming, playground, recreation hall, complete marine service, RV hookups, wet and dry docks, boat and motor rentals, heated fishing dock, cabin rental and boat launching.

(26) Port Duncan - Located on Monkey Island with facilities for sale of condos, lots, houses, cottage rental, boat slips, full service marina, ships store and boat launching.

(27) Port Ketchum - Located south of Ketchum, OK with facilities for cottage rental, meeting room, boat slips and boat launching.

(28) Red Rock Resort - Located north of Grove, OK with facilities for RV hookups, camping, convenience store, boat launching, enclosed fishing dock, slips, swimming pool and motel and cabin rental.

(29) Scotty's Cove - Located north of Langley, OK with facilities for full service marina, boat slips and boat launching.

(30) Shangri-La Marina - Located on Monkey Island with facilities for boat rental, full marine service, boat launching, wet storage, ships store and fishing guide service.

(31) Slim's Resort - Located east of Cleora, OK with facilities for overnight lodging, RV hookups, mobile homes, convenience store, cafe, boat launching, ships store, boat rentals and slips.

(32) TeraMiranda Marina-Resort - Located on Monkey Island with facilities for cottage rental, tennis courts, swimming pool, playground, boat launching, slips, full service marina and boat sales.

Hotels/Motels/Cabins/Resorts

There are thirty major commercial businesses located in the Grand Lake area that provide accommodations, etc. for hire.

(1) Anchor's End - Located south of Ketchum, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, heated fishing dock and cottage rentals.

(2) Ballerina Pier 59 - Located north of Grove, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, camping, resale of boats, heated fishing dock and cottage rentals.

(3) Blue Bluff Harbor - Located northeast of Grove, OK with facilities for mobile home lots, heated fishing dock, boat launching, wet boat storage and construction of docks.

(4) Cherokee Queen Motel - Located south of Grove, OK with facilities for swimming pool, RV hookups and rooms for hire.

(5) Courthouse Marina - Located south of Grove, OK with facilities for boat rentals, boat launching, swimming, sale and resale of boats, heated fishing dock, cottage rentals, covered boat slips, full service dock and ski shop.

(6) Cozy Motel - Located in Grove, OK with facilities for swimming pool and rooms for hire.

(7) Elk River Paradise - Located northeast of Grove, OK with facilities for Boat storage, full marine service, mobile home and RV park, convenience store, boat rental, boat launching, sale and resale of boats and motors.

(8) Fisherman's Paradise - Located northwest of Grove, OK with facilities for cabin rental, camping, RV hookups, boat launching, and personal hygiene.

(9) Four Seasons - Located northeast of Grove, OK with facilities for RV hook ups, boat launching, heated fishing dock, boat slips, swimming, laundry, convenience store, game room, boat rentals and rental cabins.

(10) Grand Lodge Motel - Located in Ketchum, OK with facilities for swimming pool, package store, club and rooms for hire.

(11) Grand Motel - Located in Grove, OK with facilities for swimming pool and rooms for hire.

(12) Hills Resort - Located south of Grove, OK with facilities for cottage rental, swimming, boat and motor rental, covered dock, wet and dry dock, boat launching, convenience store, fishing guide service and heated fishing dock.

(13) Honey Creek Resort - Located on south Main St. Grove, OK with facilities for cottage rentals, boat dock, boat launching, swimming, enclosed fishing dock, fishing pier, boat rentals, fishing guide, motel and airport pick-up.

(14) Horse Creek Resort - Located east of Bernice, OK with facilities for cottage rental, RV hookups, boat launching, dry storage, convenience store and camping.

(15) Indian Hills Resort - Located in Bernice, OK with facilities for cottage rental, swimming dock, boat launching, heated fishing dock, convenience store, marina, boat and motor sales, RV hookups and snack bar.

(16) King Point Resort - Located northeast of Grove, OK with facilities for mobile homes, cottage rental, boat and motor repairs, swimming, heated fishing dock, dry boat storage, RV hookups, boat launching and convenience store.

(17) Lakeside Motel - Located in Grove, OK with facilities for restaurant and rooms for hire.

(18) Lee's Resort - Located northeast of Grove, OK with facilities for mobile homes, RV hookups, cottage rental, boat launching, covered docks, boat rentals, heated fishing dock, swimming pool, tennis courts, playground and convenience store.

(19) Long's Resort - Located west of Grove, OK with facilities for cottage rental, boat launching, heated fishing dock, boat slips and convenience store.

(20) Monkey Island East Bay - Located on Monkey Island with facilities for cottage rentals, mobile homes, slips, full service marina and boat launching.

(21) Outrigger Motel - Located northwest of Grove, OK with facilities for enclosed heated swimming pool, boat slips, electrical plug-ins, restaurant and rooms for hire.

(22) Pla-Port Resort - Located in Grove, OK with facilities for mobile homes, swimming, playground, recreation hall, complete marine service, RV hookups, wet and dry docks, boat and motor rentals, heated fishing dock, cabin rental and boat launching.

(23) Port Duncan - Located on Monkey Island with facilities for sale of condos, lots, houses, cottage rental, boat slips, full service marina, ships store and boat launching.

(24) Port Ketchum - Located south of Ketchum, OK with facilities for cottage rental, meeting room, boat slips and boat launching.

(25) Red Rock Resort - Located north of Grove, OK with facilities for RV hookups, camping, convenience store, boat launching, enclosed fishing dock, slips, swimming pool and motel and cabin rental.

(26) Shangri-La - Monkey Island with facilities for Golf, fishing, boating, tennis courts, swimming pools, racquet ball courts, jogging trails, bowling, health spa sales and rentals of condos, motel rooms, homes.

(27) Slim's Resort - Located east of Cleora, OK with facilities for overnight lodging, RV hookups, mobile homes, convenience store, cafe, boat launching, ships store, boat rentals and slips.

(28) Smitty's Resort - Located west of Grove, OK with facilities for cottages for hire, boat and motor rental, boat launching, dry storage, heated fishing dock and bait/tackle store.

(29) TeraMiranda Marina-Resort - Located on Monkey Island with facilities for cottage rental, tennis courts, swimming pool, playground, boat launching, slips, full service marina and boat sales.

(30) Walnut Cove Resort - Located northeast of Grove, OK with facilities for RV hookups, dry boat storage, heated fishing dock and boat launching.

Mobile Home Parks

(1) Ballerina Pier 59 - located north of Grove, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, camping, resale of boats, heated fishing dock, cottage rentals and mobile home parking.

(2) Barker's Edgewater Marine - Located northwest of Grove, OK with facilities for boat launching, swimming, mobile home rental, sale and resale of boats and motors.

(3) Blue Bluff Harbor - Located northeast of Grove, OK with facilities for mobile home lots, heated fishing dock, boat launching, wet boat storage and construction of docks.

(4) King Point Resort - Located northeast of Grove, OK with facilities for mobile homes, cottage rental, boat and motor repairs, swimming, heated fishing dock, dry boat storage, RV hookups, boat launching and convenience store.

(5) Lakewood Village Resort - Located northeast of Grove, OK with facilities for mobile home parking and boat launching.

(6) Lee's Resort - Located northeast of Grove, OK with facilities for mobile homes, RV hookups, cottage rental, boat launching, covered docks, boat rentals, heated fishing dock, swimming pool, tennis courts, playground and convenience store.

(7) Leon's Harbor Hills Resort - Located west of Grove, OK with facilities for boat slips, boat launching and mobile home parking.

(8) Monkey Island East Bay - Located on Monkey Island with facilities for cottage rentals, mobile homes, slips, full service marina and boat launching.

(9) Pla-Port Resort - Located in Grove, OK with facilities for mobile homes, swimming, playground, recreation hall, complete marine service, RV hookups, wet and dry docks, boat and motor rentals, heated fishing dock, cabin rental and boat launching.

(10) Red Rock Resort - Located north of Grove, OK with facilities for RV hookups, camping, convenience store, boat launching, enclosed fishing dock, slips, swimming pool and motel and cabin rental.

(11) Shadowbrook Coves - Located south of Grove, OK with facilities for mobile home parking and boat launching.

(12) Slim's Resort - Located east of Cleora, OK with facilities for overnight lodging, RV hookups, mobile homes, convenience store, cafe, boat launching, ships store, boat rentals and slips.

Influence of Tourism on the Grand Lake Region

The Grand Lake socioeconomic region (the region specifically includes the four Oklahoma counties, Ottawa, Delaware, Mayes and Craig, in which Grand Lake is formed) is predominantly agricultural with a few manufacturing industries in the larger communities. In the earlier part of this century this region was known for it's mining operations and still maintains a small lead, zinc and cadmium mining industry. However the agricultural base of the region dominates socioeconomically, with the tourism industry contributing significantly to a somewhat limited industrial base. The following discussion focuses on the relative contribution of travel expenditures and State Park usage as estimators of the impact of tourism on the region. In addition the focus of advertising by the Grand Lake Association (located in Grove, OK) is discussed

Impact of Travel on the Grand Lake Region

Based on information provided by the United States Travel Data Center, 1989 in the form of report by the Oklahoma Tourism and Recreation Department, The Economic Impact of Travel on Oklahoma Counties, 1988, the following estimates of the impact of travel on the four counties in the Grand Lake region are possible.

These estimates represent expenditures by United States residents traveling in Oklahoma. This includes both in-state and out-of-state visitors traveling away from home overnight, or on day trips to places one hundred or more miles away from home during 1988. Commuting to work, school, military travel, transportation workers and foreign visitors are excluded. These estimates represent impacts generated in the private sector and exclude public-supported payroll and employment.

The impact of travel on the wage and salary income of Oklahoma can be estimated by multiplying a proportion of dollars spent by travelers. This proportion (as reported by the U.S. Travel Data Center) is .21 for each dollar spent on travel in Oklahoma. It is estimated that for every $52,000 spent by travelers in Oklahoma, one job is directly supported.

Tax receipts from travel expenditures contributed to federal, state and local government collections. The local receipts are most salient for this discussion and they are estimated to comprise six percent of all local tax receipts in Oklahoma. Each dollar expended on travel in Oklahoma generated about two cents of local tax revenue. Table 21 represents the 1988 travel expenditures, travel-generated payroll, employment and the local tax revenue for the four counties in the Grand Lake region.

Impact of State Park Usage on the Grand Lake Region

This section of the report estimates the economic contribution of State Park visitation on the Grand Lake regional economy.

Table 21. Impact of Travel on Grand Lake Region

County	Total Travel Expenditures	Travel Generated Payroll	Travel Generated Employment	Local Tax Receipts
Craig	$ 3,186	$ 476	50	$ 54
Delaware	$ 36,640	$ 6,801	817	$ 751
Mayes	$ 11,016	$ 1,874	207	$ 195
Ottawa	$ 28, 656	$ 5231	627	$ 602

Note: All dollar figures are in the 000's.

The Oklahoma Tourism and Recreation Department reported that State Parks and Recreation Areas were visited by over sixteen million people in 1988. This large number of visitors contributed to the Oklahoma Department of Commerce's report in 1988, that tourism is one of Oklahoma's leading industries. The proportion of visitors to Grand Lake's State Parks represents 6% of all Oklahoma State Park and Recreation

Area visitors. Refer to Table 22: State Park Attendance Grand Lake Region, for the actual number of visitors to each State Park in the Grand Lake region during 1987, 1988 and 1991.

The information on visitation was collected by the Oklahoma Department of Tourism and Recreation, Planning and Development Staff during the 1987-1988 Oklahoma State Park Visitor Survey. The data was collected by a random sample method at State Parks in Oklahoma during 1987-1988 by employees of the State Parks and Recreation Service. Individual responds were anonymous and voluntary, if refused the state of origin and a reason for refusal were requested.

The data are for State Parks in the GrandTable 6 - Table 13)Table 6 - Table 13) Lake region, which include: Bernice State Park; Disney/Little Blue State Park; Honey Creek State Park; Twin Bridges State Park and Cherokee 1-3 State Park.

When asked to estimate the expense for a days visit, respondents estimated an average cost per person of $8.79 per day. This figure when multiplied by the attendance figures for 1988 produces a direct economic

Table 22. State Park Attendance - Grand Lake Region

State Park	1987	1988	1990
Bernice	62,675	97,801	121,884
Cherokee	287,840	279,421	272,192
Disney/Little Blue	120,308	128,184	210,774
Honey Creek	126,848	111,181	267,767
Twin Bridges	322,107	314,770	330,703
Total	919,778	931,357	1,203,320

impact of 8,186,628 million dollars per year on the regional economy. This estimate does not include trip expenses for individuals who do not visit State Parks in the Grand Lake Region. With this in mind, and the evidence of extensive shoreline development, the total economic impact of lake usage on the region should be much larger than the impact of State Park usage alone. In addition if a multiplier effect is applied to the direct contribution of these monies, the beneficial input would be even greater.

Population Characteristics of the Grand Lake Region

Population Characteristics of the Four State Region

The tables in Task 5 (Table 6 - Table 13) present data on population for those counties and cities that fall within the eighty kilometer radius of Grand Lake. This radius represents the land area within which the hypothetical population of lake users resides. Due to the location of Grand Lake in the extreme northeast corner of Oklahoma the four states that are included in the eighty kilometer radius are: Kansas, Missouri, Arkansas and Oklahoma. Refer to Task 4, Figure 5 and Figure 6 for spatial reference.

Information is given for each of the four states and represented by two tables which contain: (1) the population, population per square mile, total square miles of each county within the eighty kilometer radius, total state population, total identified county population and percent of state population in identified counties; (2) the population of significant towns and cities within the eighty kilometer radius and whether or not they lie within a Standard Metropolitan Statistical Area.

Source: County and City Data Book, 1988, United States Department of Commerce, Bureau of the Census

Population Characteristics of the Four County Region

Various data sources are combined to provide population characteristics of the four county region, by county, within which Grand Lake is formed. Refer to Task 4, Figure 5 and Figure 6 for spatial reference.

Sources: 1980 Population: U.S. Bureau of the Census, 1980 Summary Tape File A.

1950-1970 Population: U.S. Bureau of the Census, General Characteristics of the Population.

1990-2000 Population: Center for Economic and Management Research, University of Oklahoma, Statistical Abstract of Oklahoma 1980, pp. 20-23.

Acres of Land/Water: Oklahoma Soil Conservation Service, "Oklahoma Land Inventory," January 1978.

Spuare Miles: U.S. Bureau of Census, Geography Division, Computer Graphic Staff, 1980.

U.S. Bureau of the Census, 1964, 1968, 1974, 1978 Census of Agriculture.

Oklahoma Soil Conservation Service, "Oklahoma Conservation Needs Inventory," March, 1970, p. 11; and "Oklahoma Land Inventory," January 1978, p. 5.

1950, 1960, 1970 data: U.S. Bureau of the Census, General Social and Economic Characteristics.

1950-1960 Per Capita Income: Bureau of Business and Economic Research, University of Oklahoma, "County Personal Income in Oklahoma," Appendix B, Table B-4.

1970, 1979 Per Capita Income: Bureau of Economic Analysis, "Per Capita Personal Income in Counties in Selected Years."

1950-1970 Median Family Income: U.S. Bureau of the Census, Census of Population, General Social And Economic Characteristics.

1950-1970 Labor Force: U.S. Bureau of Census, General Social and Economic Characteristics.

1980 Labor Force: Oklahoma Employment Security Commission, "1980 Preliminary Labor Force Data."

1970 Participation Rates: Oklahoma Employment Security Commission, "Manpower Information For Affirmative Action Programs."

Bureau of Economic Analysis, "Employment by Type and Broad Industrial Sources 1973-1979," (table 25.00)

Pre-1972 Data: Peach, W. Nelson, Richard W. Pole, and James D. Tarver, Oklahoma state University Research Foundation, "County Building Block Data for Regional Analysis-Oklahoma," March 1965.

1972, 1977 Data: U.S. Bureau of Census, Census of Retail Trade.

County Profile: Craig

General Information

SMSA : Non-SMSA County

Largest City : Vinita 1980 Population : 6,740

Acres of Land : 488,331 Acres of Water : 629

Total Acres : 488,960 Square Miles : 763

Population

	Population	Population Change	Density	Percent Urban
1950	18,263	------	23.9	30.2
1960	16,303	-1,960	21.4	37.0
1970	14,722	-1,581	19.3	39.7
1980	15.014	292	19.7	44.9
1990- Projected	14,600	-414	19.1	----
2000-Projected	14,400	-200	18.9	----

Agriculture

	1964	1969	1974	1978
Number of Farms	1,324	1,255	1,049	1,117
Avg. Acres/Farm	326	340	378	357
Percent of Land Devoted to Farms	88.30	87.30	81.10	81.60
Avg. Value/Farm	$34,949	$54,820	$118,513	$33,349
Irrigated Acres	181	4	---	532
Farms With Sales > $20,000	81	131	160	263
Market Value of All Ag. Products Sold in 000's	$9,744	$15,739	$22,203	$33,349

County Profile: Craig
(continued)

Land Use

	Cropland	Pastureland	Rangeland	Forestland
1958	190,790	7,154	222,364	46,207
1967	133,492	94,279	210,973	25,285
1978	61,425	200,208	153,141	27,690

Per Capita and Median Family Income

	Per Capita Income	Median Family Income
1950	$591	$1,510
1960	$1,276	$3,691
1970	$2,157	$6,215
1980	$8,933	N/A

Labor Force

	Total Labor Force	Employed	Unemployed	Unemployment Rate
1950	5,586	5,440	146	2.61
1960	5,162	4,937	225	4.36
1970	5,244	5,096	148	2.82
1980	7,200	6,860	340	4.72

County Profile: Craig
(continued)

Employment Data

	1973	1976	1979
Total Wage & Salary Employment	5,074	5,377	5,217
Farm	153	183	173
Non- Farm	4,921	5,194	4,954
Private	2,479	2,603	3,157
Government	2,442	2,591	1,797

Private Sector Employment

	1973	1976	1979
Ag. Serv., Forest, Fisheries	-----	25	32
Mining	-----	350	532
Construction	56	57	72
Manufacturing	639	372	528
Transportation	308	324	368
Wholesale Trade	23	194	202
Retail Trade	693	677	764
Fin., Insur., Real Estate	112	126	150

Government Employment

	1973	1976	1979
Fed.,Civilian	78	60	67
Fed.,Military	98	86	84
State and Local	2,266	2,445	1,646

County Profile: Ottawa

General Information

SMSA : Non-SMSA County

Largest City : Miami 1980 Population : 14,237

Acres of Land : 296,651 Acres of Water : 12,496

Total Acres : 309,120 Square Miles : 484

Population

	Population	Population Change	Density	Percent Urban
1950	32,218	-----	66.6	48.9
1960	28,301	-3,917	58.5	54.5
1970	29,800	1,499	61.6	55.3
1980	32,870	3,070	67.9	51.1
1990-Project.	34,600	1,730	71.5	-----
2000-Project.	36,500	1,900	75.4	-----

Agriculture

	1960	1969	1974	1978
Number of Farms	990	1,041	835	927
Avg. Acres/Farm	211	221	254	237
% Land Devoted to Farms	70.90	77.50	71.50	74.00
Avg. Value/Farm	$31,732	$45,126	$93,255	$141,374
Irrigated Acres	193	198	222	226
Farms with Sales >$20,000	37	76	151	192
Market Value of All Ag. Products Sold in 000's	$4,593	$6,869	$13,314	$18,225

County Profile: Ottawa
(continued)

Land Use

	Cropland	Pastureland	Rangeland	Forestland
1958	118,564	9,949	60,312	82,953
1967	102,443	64,680	28,406	78,400
1978	66,942	128,497	58,159	13,211

Per Capita and Median Family Income

	Per Capita Income	Median Family Income
1950	$1,044	$2,326
1960	$1,569	$4,120
1970	$2,482	$7,264
1980	$8,975	N/A

Labor Force

	Total Labor Force	Employed	Unemployed	Unemployment Rate
1950	10,916	10,069	847	7.76
1960	9,368	8,797	571	6.10
1970	11,394	10,831	563	4.94
1980	13,300	12,075	1,225	9.21

County Profile: Ottawa (continued)

Employment Data

	1973	1976	1979
Total Wage & Salary Employment	9,574	9,795	11,546
Farm	205	263	249
Non-Farm	9,369	9,532	11,297
Private	7,516	7,538	9,282
Government	1,853	1,994	2,015

Private Sector Employment

	1973	1976	1979
Ag. Serv., Forest, Fisheries	35	24	30
Mining	59	78	62
Construction	286	246	243
Manufacturing	3,640	3,269	4,599
Transportation	226	206	148
Wholesale Trade	207	358	386
Retail Trade	1,421	1,453	1,634
Fin., Insur., Real Estate	288	282	323

Government Employment

	1973	1976	1979
Fed., Civilian	192	199	231
Fed., Military	217	201	185
State and Local	1,444	1,594	1,599

County Profile: Delaware

General Information

SMSA : Non-SMSA County

Largest City : Grove 1980 Population : 3,378

Acres of Land : 451,483 Acres of Water : 47,077

Total Acres : 498,560 Square Miles : 792

Population

	Population	Population Change	Density	Percent Urban
1950	14,734	-----	18.6	0.0
1960	13,198	-1,536	16.7	0.0
1970	17,767	4,569	22.4	0.0
1980	23,946	6,179	30.2	14.1
1990-Project.	23,900	-46	30.2	-----
2000-Project.	26,400	2,500	33.3	-----

Agriculture

	1964	1969	1974	1978
Number of Farms	1,422	1,165	1,011	1,170
Avg. Acres/Farm	184	223	234	245
% Land Devoted to Farms	57.40	57.50	52.30	63.30
Avg. Value/Farm	$22,151	$40,691	$83,099	$147,513
Irrigated Acres	448	527	156	132
Farms with Sales >$20,000	73	131	155	248
Market Value of All Ag. Products Sold in 000's	$6,496	$11,256	$16,147	$26,809

County Profile: Delaware
(continued)

Land Use

	Cropland	Pastureland	Rangeland	Forestland
1958	98,887	432	53,278	291,350
1967	63,512	60,695	62,772	254,200
1978	12,698	220,824	7,473	182,732

Per Capita and Median Family Income

	Per Capita Income	Median Family Income
1950	$322	$1,108
1960	$727	$2,352
1970	$1,867	$4,398
1980	$5,001	N/A

Labor Force

	Total Labor Force	Employed	Unemployed	Unemployment Rate
1950	4,323	4,182	147	3.26
1960	3,634	3,435	199	5.48
1970	4,983	4,761	222	4.46
1980	9,850	9,210	640	6.50

Employment Data

	1973	1976	1979
Total Wage & Salary Employment	2,681	3,177	4,009
Farm	160	188	179
Non-Farm	2,521	2,989	3,830
Private	1,670	2,053	2,887
Government	851	936	943

Private Sector Employment

	1973	1976	1979
Ag. Serv., Forest, Fisheries	26	28	34
Mining	0	0	0
Construction	131	158	446
Manufacturing	296	408	481
Transportation	55	65	77
Wholesale Trade	47	58	108
Retail Trade	397	466	600
Fin., Insur., Real Estate	63	105	186

Government Employment

	1973	1976	1979
Fed., Civilian	60	70	76
Fed., Military	130	122	117
State and Local	661	744	750

County Profile: Mayes

General Information

SMSA : Non-SMSA County

Largest City : Pryor Creek 1980 Population : 8,483

Acres of Land : 393,978 Acres of Water : 46,342

Total Acres : 440,320 Square Miles : 683

Population

	Population	Population Change	Density	Percent Urban
1950	19,743	-----	28.9	22.7
1960	20,073	330	29.4	32.3
1970	23,302	3,229	34.1	30.3
1980	32,261	8,959	47.2	26.3
1990-Project.	40,500	8,239	59.3	-----
2000-Project.	55,300	14,800	81.0	-----

Agriculture

	1964	1969	1974	1978
Number of Farms	1,433	1,247	1,103	1,258
Avg. Acres/Farm	211	225	221	222
% Land Devoted to Farms	70.00	67.80	58.70	67.10
Avg. Value/Farm	$28,453	$47,237	$86,974	$152,673
Irrigated Acres	310	98	58	232
Farms with Sales >$20,000	47	104	123	211
Market Value of All Ag. Products Sold in 000's	$5,705	$8,876	$10,365	$19,112

County Profile: Mayes
(continued)

Land Use

	Cropland	Pastureland	Rangeland	Forestland
1958	134,334	29,784	81,997	113,805
1967	65,536	115,705	75,665	112,800
1978	25,309	195,785	44,359	80,177

Per Capita and Median Family Income

	Per Capita Income	Median Family Income
1950	$501	$1,511
1960	$1,160	$3,468
1970	$2,184	$6,255
1980	$7,228	N/A

Labor Force

	Total Labor Force	Employed	Unemployed	Unemployment Rate
1950	6,147	5,831	316	5.14
1960	6,139	5,757	382	6.22
1970	7,807	7,326	481	6.16
1980	15,640	14,570	1,070	6.84

Employment Data

	1973	1976	1979
Total Wage & Salary Employment	6,007	7,533	8,254
Farm	131	156	147
Non-Farm	5,876	7,377	8,107
Private	4,294	5,628	6,445
Government	1,582	1,749	1,662

Private Sector Employment

	1973	1976	1979
Ag. Serv., Forest, Fisheries	62	--	--
Mining	--	14	--
Construction	232	390	730
Manufacturing	1,854	2,569	2,575
Transportation	179	192	208
Wholesale Trade	--	141	--
Retail Trade	921	1,145	1,354
Fin., Insur., Real Estate	130	--	--

Government Employment

	1973	1976	1979
Fed., Civilian	70	69	90
Fed., Military	170	169	160
State and Local	1,342	1,511	1,412

Discussion

The data presented in this task point to the large numbers of people who live in the Grand Lake region that are dependant upon the lake for economic reasons. Many of the communities surrounding the lake could not support their population levels without the tourism associated with the lake. If Grand Lake were to deteriorate in water quality to the extent that the activities now conducted on the lake had to be curtailed, the resulting economic consequences would be severe, both for the state of Oklahoma and the commonties that depend on tourism for a large part of their economic base.

TASK 8: Comparative Lake Use

OBJECTIVE: Comparison of the beneficial uses of GrandLake with other lakes within a 80 kilometer radius.

SOURCES: Census Data

Consultation with Grand Lake Association

Consultation with and publications from Oklahoma Tourism and Recreation Department

Publications from Oklahoma Water Resources Board

Facility Characteristics of Grand Lake

Public Access Points to Grand Lake

Grand River Dam Authority has control over all property up to an elevation of 750 msl on Grand Lake and allows free public access to these lands. There is no charge to the public for the right to engage in hunting, fishing, swimming or non-commerical boating. No camping is permitted on GRDA property except in areas designated as public use areas. There are different taking elevations in the upper end of Grand Lake that alter this control however these are not significant in terms of public access.

There are two general types of public access points which allow for boating, fishing and other watersports, in some combination of these three types of activities. The two types include: (1) state park access points; and (2) public access points that are not supported by the state. The various commercial facilities available to the public will be discussed in a following section. Please refer to Task 4, ? and ?, for spatial reference to Grand Lake.

State Park Access Points

There are seven public access points associated with the five state supported park areas on Grand Lake. These state park areas include Bernice State Park, Cherokee State Park Areas 1, 2 and 3, Disney State Park/Little Blue, Honey Creek State Park and Twin Bridges State Park. The following discussion describes the characteristics of each of these state parks.

Bernice State Park is located on Hwy 85A at Bernice, OK on the Horse Creek arm of Grand Lake and covers eighty-eight acres of state owned property in Delaware county OK. The site allows for fishing, swimming and boating with one lighted boat ramp. Other facilities include twenty-one picnic tables, thirty-three electric hookups for camping and twenty unimproved camping sites, one comfort station with showers, one comfort station without showers, one sanitary dump station and one playground.

Cherokee State Park Areas 1, 2 and 3. Cherokee # 1 is located on the south side of Langley, below Pensacola Dam on the Grand River and allows for fishing and boating with one lighted boat ramp. Other facilities include twenty-eight picnic tables, one group shelter, eighteen electric hookups for camping, forty unimproved camp sites and one comfort station without showers.

Cherokee # 2 is located on the east end of Pensacola Dam and allows for fishing, boating and other watersports with one lighted boat ramp. Other facilities include twenty-two picnic tables, one group shelter, twelve electric hookups for camping, twenty-five unimproved camp sites, one comfort station with showers, one sanitary dump station and one playground.

Cherokee # 3 is located one half mile east of Pensacola Dam beside the east spillway and the site allows for fishing, boating and other watersports with one lighted boat ramp. Other facilities include 'wenty picnic tables, one group shelter, four electric RV sites and twenty unimproved RV sites, one comfort station with showers, one sanitary dump station

The total state owned acreage included in the three Cherokee sites is fourty-three. All three sites are located in Mayes county OK.

Disney State Park/Little Blue, the Disney site is located on OK State Hwy 28 south of Disney, OK below the spillway and allows for fishing and boating with one lighted boat ramp. There are twenty-eight picnic tables, four individual shelters, one group shelter, twenty-five unimproved RV sites and one playground. Disney state park covers twenty acres of state owned property.

The Little Blue site is located below the spillway. No large motors are allowed in this area, only fishing boats with small trolling motors. There are ten picnic tables and fifteen unimproved RV sites. Little Blue covers twelve acres of state owned property.

Honey Creek State Park is located in Grove, OK one mile west off of U.S. Hwy 59 on State Park road and allows for fishing and boating with one lighted boat ramp. There are ninety-seven picnic tables, two group shelters, fifty-six semi-modern (electric) camp sites, eighty unimproved camp sites, two comfort stations with showers, one comfort station without showers, one sanitary dump station, one swimming pool with bathhouse (leased to and maintained by the city of Grove, OK, one playground and one lessee on site that rents boats, motors, paddleboats, jet skis and operates a snack bar. The Honey Creek site covers thirty acres of state owned property.

Twin Bridges State Park is located seven miles east of Fairland, OK on U.S. Hwy 60 and allows for fishing and boating with two lighted boat ramps and one unlighted boat ramp. There are ninety-two picnic tables, nine individual shelters, four group shelters, seventy-six semi-modern (electric) camp sites, one hundred unimproved camp sites, two comfort stations with showers, two comfort stations without showers, one sanitary dump station, one volleyball court, two horseshoe pits, three playgrounds and one lessee on site that operates an enclosed fishing dock, rents paddleboats, canoes, boats, motors, sells bait, tackle and gas. The Twin Bridges site covers sixty-three acres of state owned property.

NonState Supported Access Points

There are ten public access points with boat launching facilities on Grand Lake that are not state supported. They are either county or community supported and the majority of these are located on the eastern shore of Grand Lake. Those situations where communities maintain boat launching facilities, as the town of Grove, OK does on the Wolf Creek arm of Grand Lake, are few and far between and do not contribute extensively to overall lake usage.

In addition to these ten access points there are an additional sixteen public access points that do not maintain boat launching facilities on Grand Lake. They are either county or community supported and are used for fishing, swimming and other non power boat related activities.

Other public access points can be found around the lake shore which are not identified as maintained boat launch sites. These access points result from the corresponding right of ways associated with old roadways that were covered by the lake. These road beds and the roads associated with them allow for public access due to state or county ownership of these lands to the taking level of the Grand River Dam Authority. Not only are these types of access points numerous but they are also largely undocumented. They are however utilized by the public and should be considered when assessing the overall usage of the lake. It should be understood that although these sites are utilized by the public the relative contribution of these sites to overall lake use is hard to estimate. With the large number of well maintained boat launch sites, commercial, public and private, it is reasonable to say that these undocumented sites contribute little to overall lake use.

Description of Types and Sizes of Private and Commercial Access Points

There are 3315 private docks and 134 commercial docks registered on Grand Lake. The large number of commercial and private docks and access points reflect the open use of the shoreline of Grand Lake. This situation is the result of control of the shoreline by the Grand River Dam Authority rather than the Corps of Engineers which, in many cases, limits shoreline development. The Authority's regulations allowing for extensive development of the shoreline along with the lengthy history of Grand Lake (fifty years) has produced the dense settlement pattern (number of homes) and large number of commercial businesses along the shoreline of Grand Lake.

Private Access Points

Due to the large number of private docks (3315) on Grand Lake and the variation in type and size, a detailed examination of these docks is precluded. Based on consultation with the Lake Patrol most private docks are located on the southern two thirds of the lake. This is due to the nature of the lake (which tends to be deeper and wider closer to the dam) and due to the relative proximity of the southern sections of the lake to larger population centers (i.e., Langley, Ketchum, Grove, and Jay, OK).

Commercial Access Points

Due to the large number of commercial docks (134) the discussion will focus on 32 major commercial marinas operating on Grand Lake. The following is a discussion of the facilities available and location of each of these marinas.

(1) Anchor's End - Located south of Ketchum, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, heated fishing dock and cottage rentals.

(2) Arrowhead Yacht Club - Located east of Ketchum, OK with facilities for complete marine service, including sales and storage, and a full service marina.

(3) Ballerina Pier 59 - Located north of Grove, OK with facilities for boat rentals, boat launching, swimming, full RV hookups, camping, resale of boats, heated fishing dock and cottage rentals.

(4) Barker's Edgewater Marine - Located northwest of Grove, OK with facilities for boat launching, swimming, mobile home rental, sale and resale of boats and motors.

(5) Blue Bluff Harbor - Located northeast of Grove, OK with facilities for mobile home lots, heated fishing dock, boat launching, wet boat storage and construction of docks.

(6) Cherokee Yacht Club - Located on Duck Creek, with full service country club environment, including swimming pool, tennis court, dining and party facilities and a full service marina.

(7) Coons Marine - Located north of Grove, OK with facilities for inside and outside boat storage, repairs, sales of new and used boats and motors and boat launching.

(8) Courthouse Marina - Located south of Grove, OK with facilities for boat rentals, boat launching, swimming, sale and resale of boats, heated fishing dock, cottage rentals, covered boat slips, full service dock and ski shop.

(9) Dick Lane Kawaski-Yamaha, Port Carlos - Located east of Ketchum, OK with facilities for jet ski rental and boat launching.

(10) Elk River Marina - Located northeast of Grove, OK with facilities for sale and resale of boats and motors, repairs and boat launching.

(11) Elk River Paradise - Located northeast of Grove, OK with facilities for Boat storage, full marine service, mobile home and RV park, convenience store, boat rental, boat launching, sale and resale of boats and motors.

(12) Four Seasons - Located northeast of Grove, OK with facilities for RV hook ups, boat launching, heated fishing dock, boat slips, swimming, laundry, convenience store, game room, boat rentals and rental cabins.

(13) Grand Lake Charter and Rentals - Located on Honey Creek State Park, Grove, OK with facilities for boat launching, charter service and boat rentals.

(14) Harbors View Marina - Located southeast of Cleora, OK with facilities for boat and motor sales and repair, full service marina and boat launching.

(15) Hi-Lift Marina - Located east of Disney, OK with facilities for dry dock storage, covered slips, ships store, sales, service and full service marina.

(16) Hills Resort - Located south of Grove, OK with facilities for cottage rental, swimming, boat and motor rental, covered dock, wet and dry dock, boat launching, convenience store, fishing guide service and heated fishing dock.

(17) Honey Creek Resort - Located on south Main St. Grove, OK with facilities for cottage rentals, boat dock, boat launching, swimming, enclosed fishing dock, fishing pier, boat rentals, fishing guide, motel and airport pick-up.

(18) Indian Hills Resort - Located in Bernice, OK with facilities for cottage rental, swimming, boat launching, heated fishing dock, convenience store, full service marina, boat and motor rental, RV hookups and snack bar.

(19) Jerry's Marina and Storage - Located in Bernice, OK with facilities for lift repair, barge service, dock construction, boat sales, wet slips, dry storage and boat launching.

(20) King Point Resort - Located northeast of Grove, OK with facilities for mobile homes, cottage rental, boat and motor repairs, swimming, heated fishing dock,

dry boat storage, RV hookups, boat launching and convenience store.

(21) Lee's Resort - Located northeast of Grove, OK with facilities for mobile homes, RV hookups, cottage rental, boat launching, covered docks, boat rentals, heated fishing dock, swimming pool, tennis courts, playground and convenience store.

(22) Long's Resort - Located west of Grove, OK with facilities for cottage rental, boat launching, heated fishing dock, boat slips and convenience store.

(23) Monkey Island East Bay - Located on Monkey Island with facilities for cottage rentals, mobile homes, slips, full service marina and boat launching.

(24) Out of the Ordinary at Pier III - Located south of Grove, OK with facilities for cottage rental, boat rental, ships store, covered boat slips, restaurant, full service marina and boat launching.

(25) Pla-Port Resort - Located in Grove, OK with facilities for mobile homes, swimming, playground, recreation hall, complete marine service, RV hookups, wet and dry docks, boat and motor rentals, heated fishing dock, cabin rental and boat launching.

(26) Port Duncan - Located on Monkey Island with facilities for sale of condos, lots, houses, cottage rental, boat slips, full service marina, ships store and boat launching.

(27) Port Ketchum - Located south of Ketchum, OK with facilities for cottage rental, meeting room, boat slips and boat launching.

(28) Red Rock Resort - Located north of Grove, OK with facilities for RV hookups, camping, convenience store, boat launching, enclosed fishing dock, slips, swimming pool and motel and cabin rental.

(29) Scotty's Cove - Located north of Langley, OK with facilities for full service marina, boat slips and boat launching.

(30) Shangri-La Marina - Located on Monkey Island with facilities for boat rental, full marine service, boat launching, wet storage, ships store and fishing guide service.

(31) Slim's Resort - Located east of Cleora, OK with facilities for overnight lodging, RV hookups, mobile homes, convenience store, cafe, boat launching, ships

store, boat rentals and slips.

(32) TeraMiranda Marina-Resort - Located on Monkey Island with facilities for cottage rental, tennis courts, swimming pool, playground, boat launching, slips, full service marina and boat sales.

Attendance Levels at Grand Lake State Parks and Impact of State Park Usage on the Grand Lake Region

This section of the report estimates the economic contribution of State Park visitation on the Grand Lake regional economy. The Oklahoma Tourism and Recreation Department reported that State Parks and Recreation Areas were visited by over sixteen million people in 1988. This large number of visitors contributed to the Oklahoma Department of Commerce's report in 1988, that tourism is one of Oklahoma's leading industries. The proportion of visitors to Grand Lake's State Parks represents 6% of all Oklahoma State Park and Recreation Area visitors. Refer to Table 23: State Park Attendance on Grand Lake, for the actual number of visitors to each State Park on Grand Lake during 1987, 1988 and 1991.

The information on visitation was collected by the Oklahoma Department of Tourism and Recreation, Planning and Development Staff during the 1987-1988 Oklahoma State Park Visitor Survey. The data was collected by a random sample method at State Parks in Oklahoma during 1987-1988 by employees of the State Parks and Recreation Service. Individual responds were anonymous and voluntary, if refused the state of origin and a reason for refusal were requested.

The data are for State Parks in the Grand Lake region, which include: Bernice State Park; Disney/Little Blue State Park; Honey Creek State Park; Twin Bridges State Park and Cherokee 1-3 State Park.

When asked to estimate the expense for a days visit, respondents estimated an average cost per person of $8.79 per day. This figure when multiplied by the attendance figures for 1988 produces a direct economic impact of 8,186,628 million dollars per year on the regional economy. This estimate does not include trip

Table 23. Annual number of visitors to state parks on Grnnd Lake.

State Park	1987	1988	1990
Bernice	62,675	97,801	121,884
Cherokee	287,840	279,421	272,192
Disney/Little Blue	120,308	128,184	210,774
Honey Creek	126,848	111,181	267,767
Twin Bridges	322,107	314,770	330,703
Total	919,778	931,357	1,203,320

expenses for individuals who do not visit State Parks in the Grand Lake Region. With this in mind, and the evidence of extensive shoreline development, the total economic impact of lake usage on the region should be much larger than the impact of State Park usage alone. In addition if a multiplier effect is applied to the direct contribution of these monies, the beneficial input would be even greater.

Facility Characteristics of Lakes Within Eighty Kilometer Radius

There are five major Oklahoma lakes within the eightykilometer radius of Grand Lake (Task 4, ?). The five Oklahoma lakes are: Oologah, Hudson, Fort Gibson, Spavinaw, and Eucha (Figure 7, Figure 8, Figure 9, Figure 10, and Figure 11, respectively). However, there are no significant lakes within the eighty kilometer radius in Kansas, Missouri or Arkansas. Beaver Lake in Arkansas is just outside this radius as is Table Rock Lake in Missouri, and there are no major lakes within this eighty kilometer radius in Kansas.

The public access points available at each of these lakes will be discussed in the following section, please refer to each lake's map for spatial orientation to the access points around each lake and other relevant sites. Prior to that discussion a brief introduction to the stated purposes and history of each of these lakes is necessary.

Oologah Lake is located in Rodgers County, OK and was authorized by

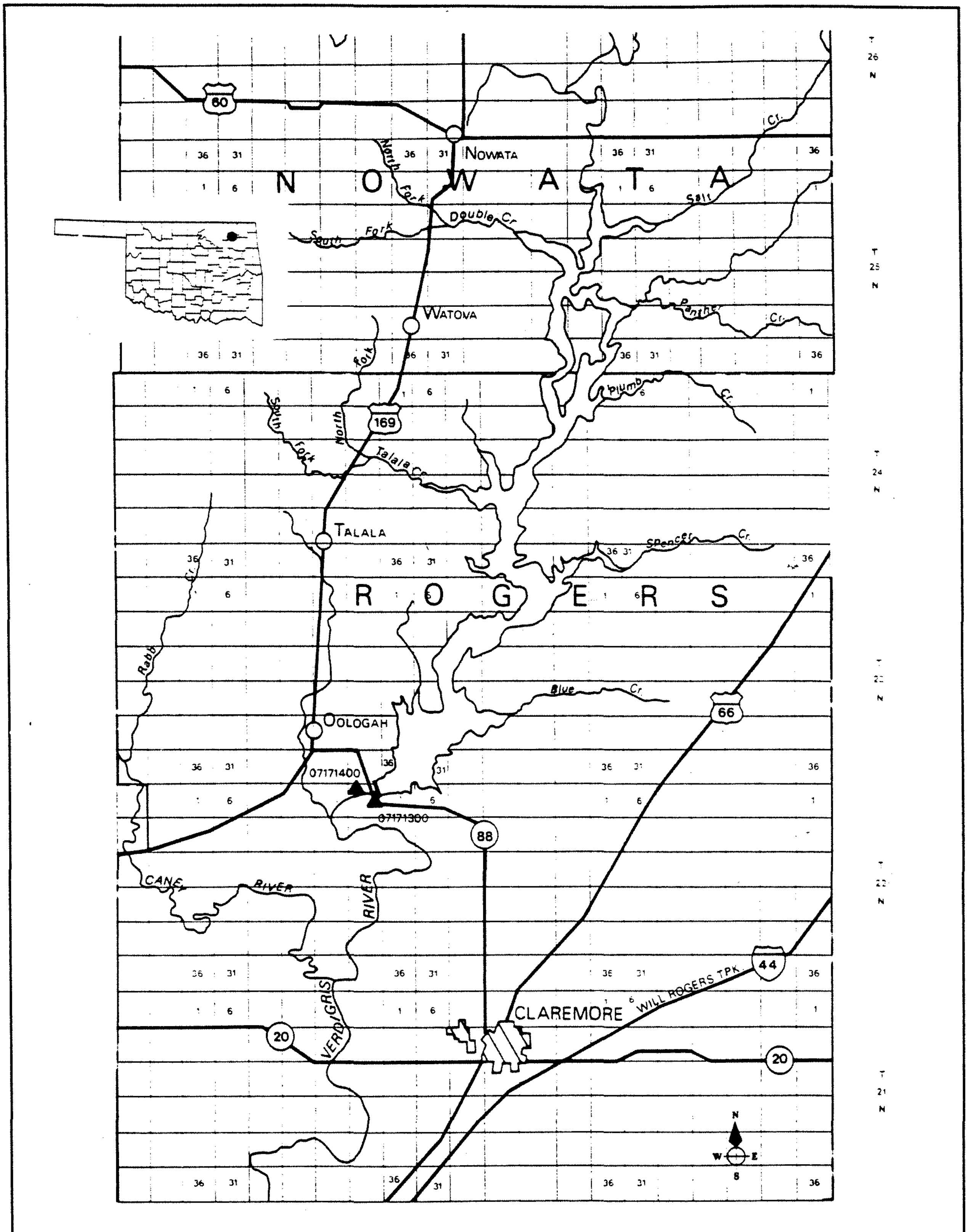


Figure 7. Map of Lake Oolagah, Oklahoma (OWRB).

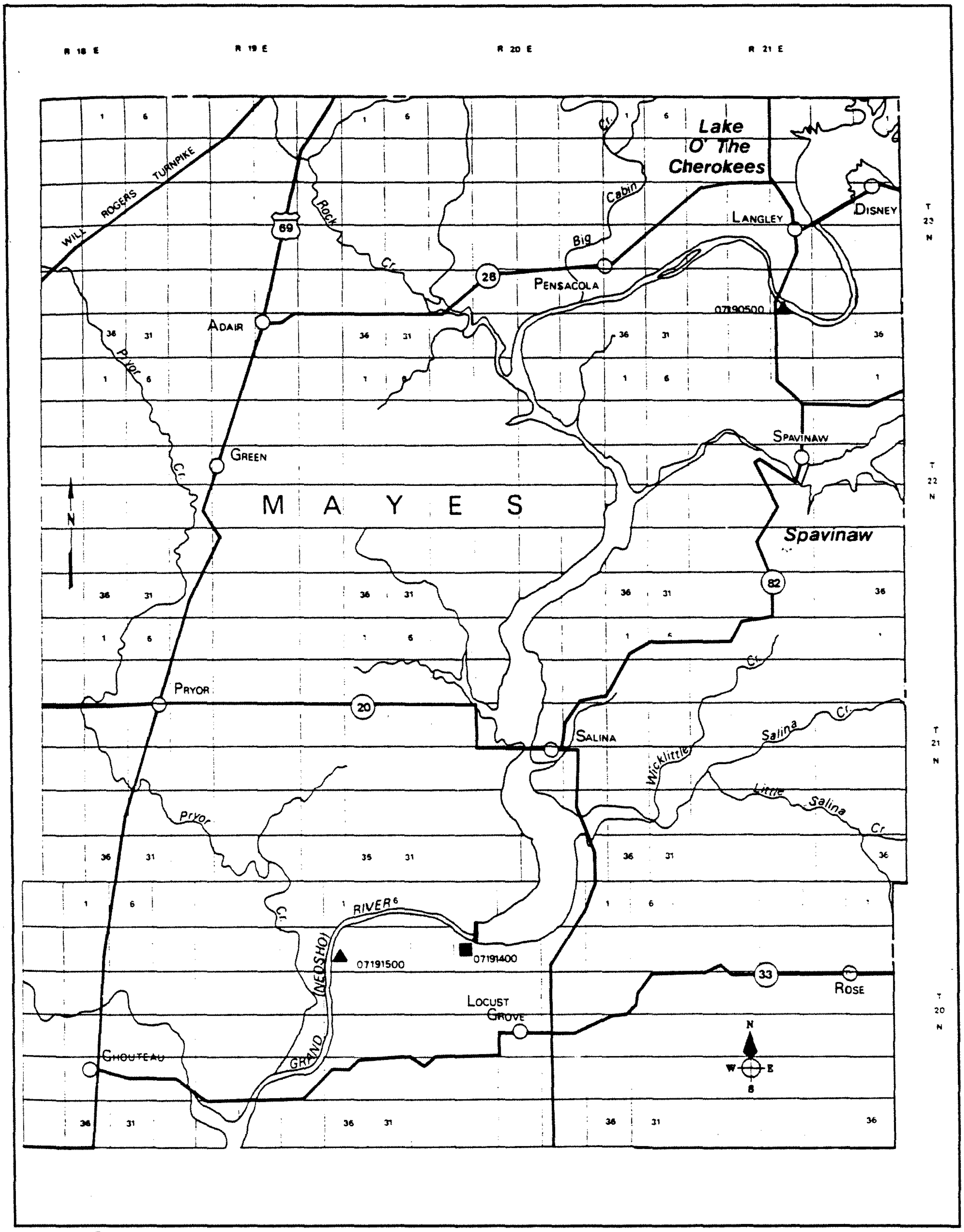


Figure 8. Map of Lake Hudson, Oklahoma (OWRB).

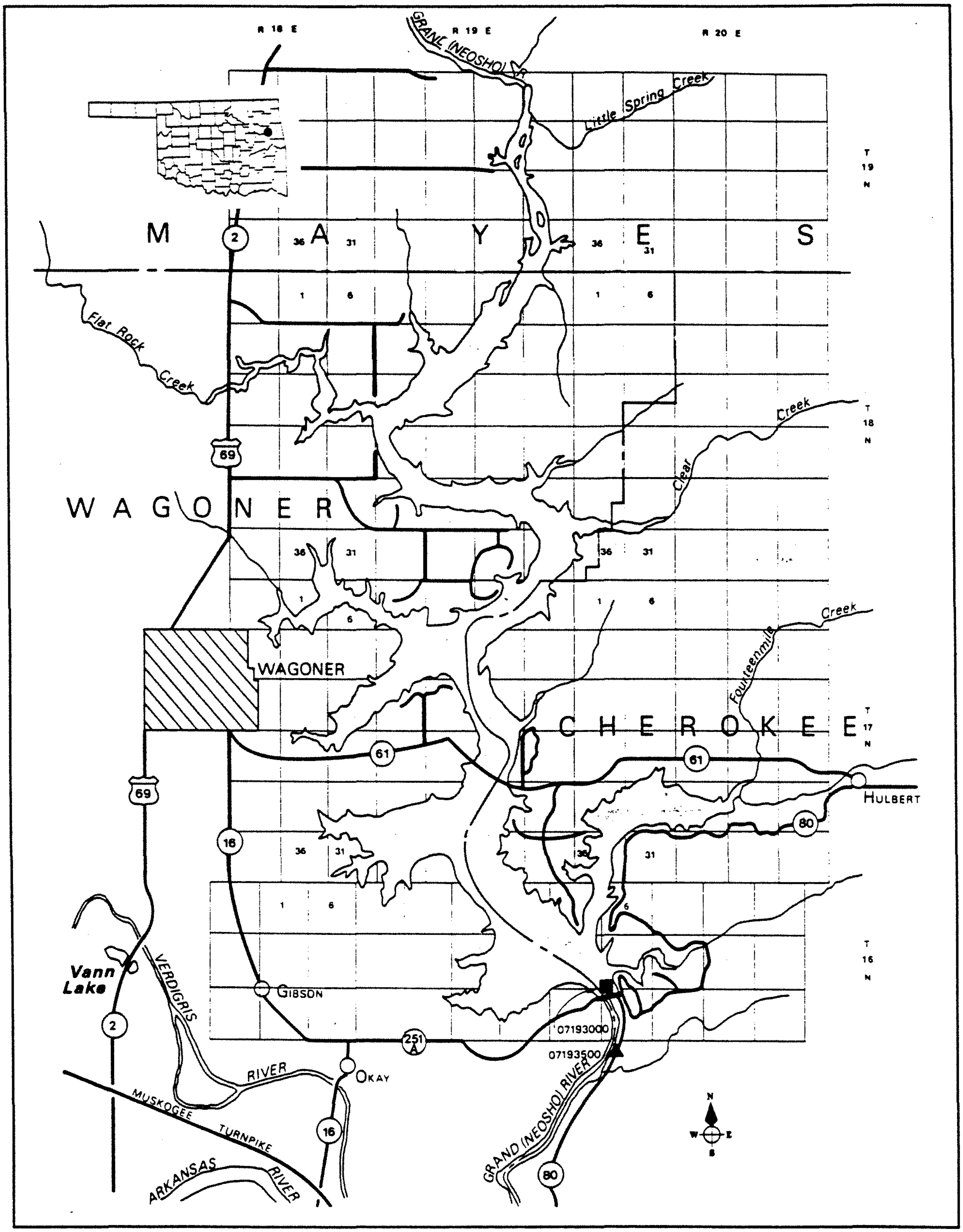


Figure 9. Map of Lake Fort Gibson, Oklahoma (OWRB).

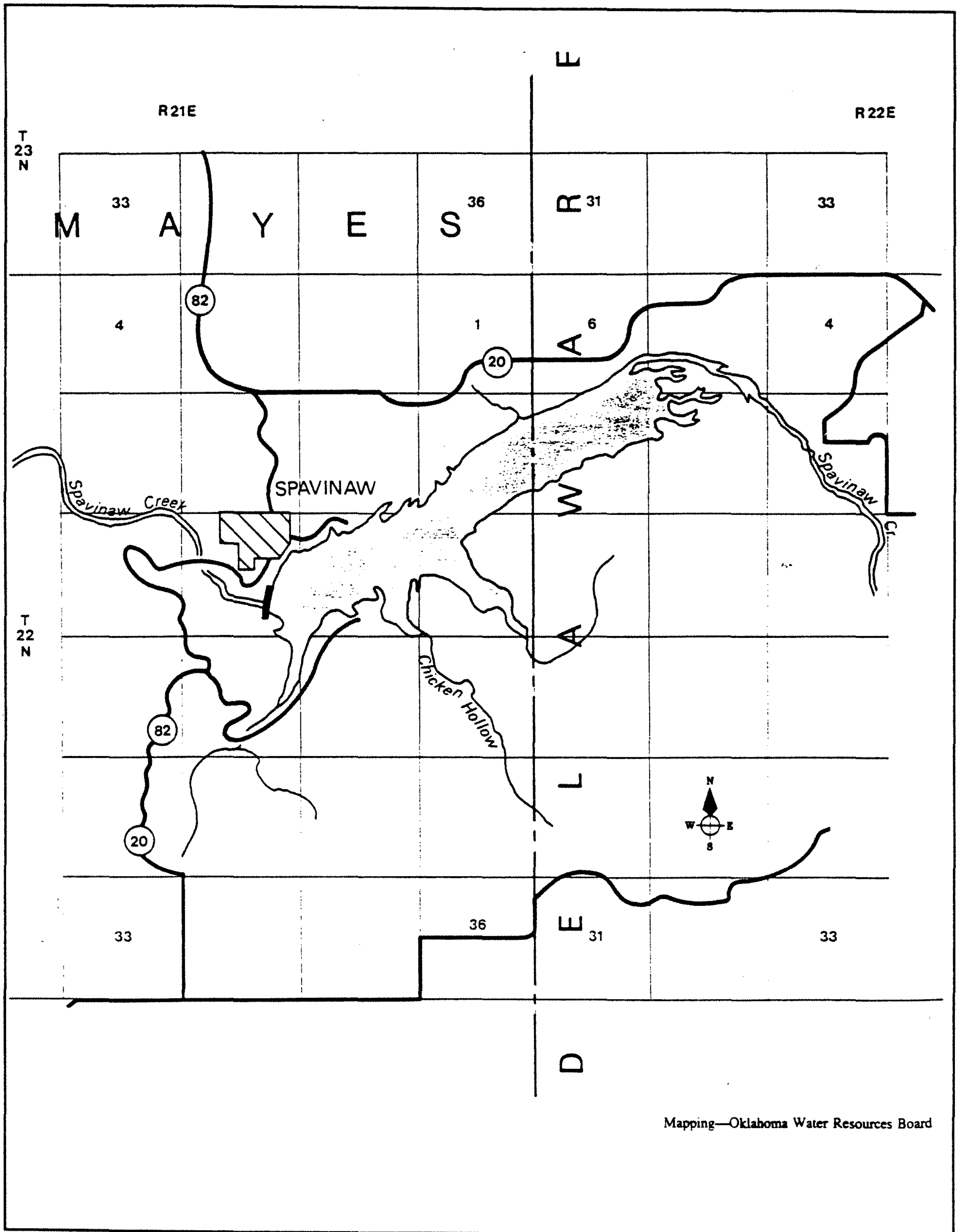


Figure 10. Map of Spavinaw Lake, Oklahoma (OWRB).

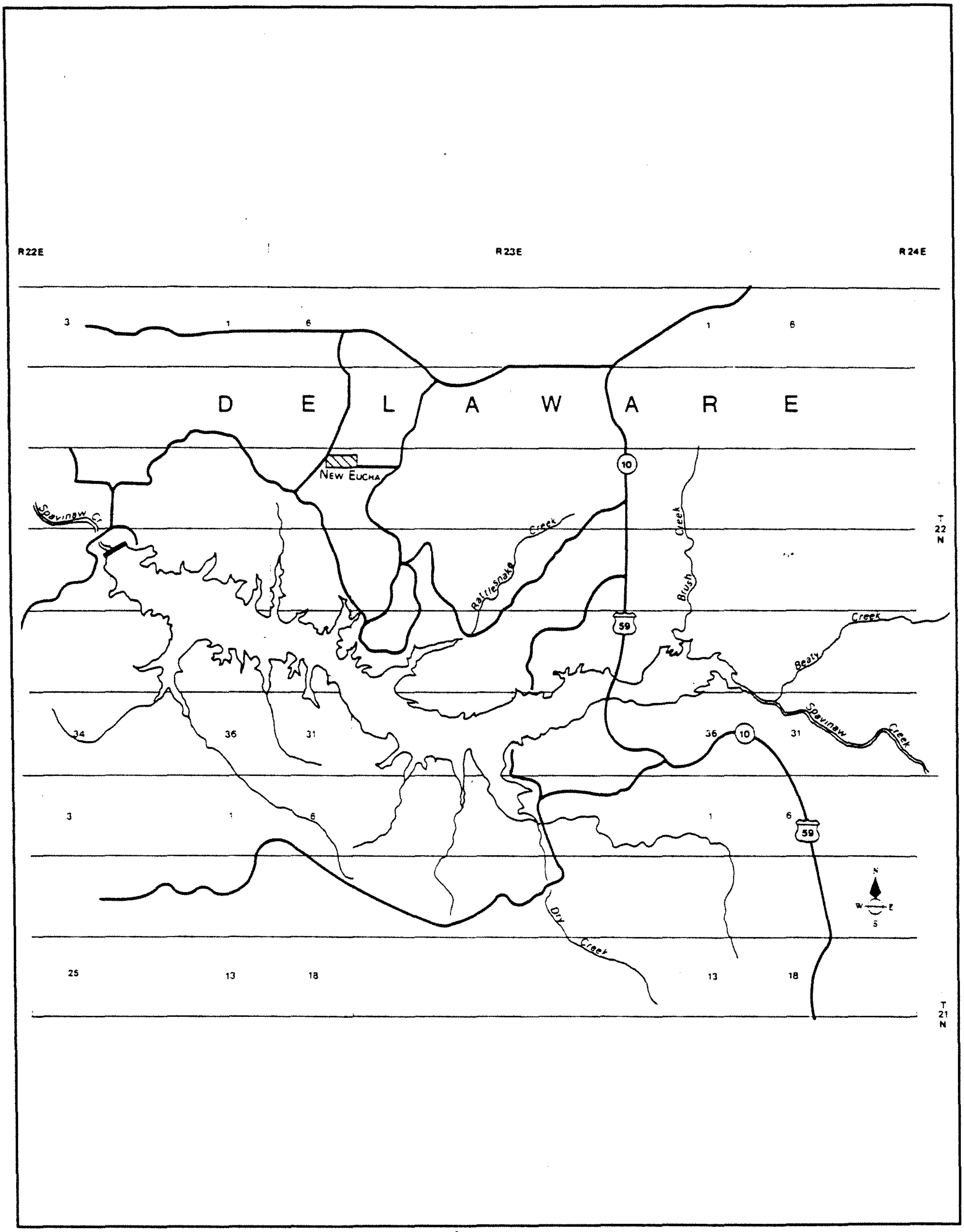


Figure 11. Map of Lake Eucha, Oklahoma (OWRB).

Congress in 1938, however do to various circumstances it was not completely constructed until 1963 by the United States Army Corps of Engineers. It occupies a primary role in the Arkansas river navigation project and as a source of flood control on the Verdigris River. In addition it has electrical power generating functions and water supply functions to the cities of Tulsa, Collinsville and Claremore, as well as several rural water districts and one private utility company. Oologah Lake has a 180 mile shoreline that is controlled by the Corps of Engineers, therefore shoreline development is limited. The estimated monetary benefits from flood prevention total $44,314,000 to 1983.

Lake Hudson is located in Mayes County, OK and construction by Grand River Dam Authority (GRDA) was completed in 1964. The dam which forms the lake in the Grand River basin, 30 miles downstream of Pensacola Dam (Grand Lake), is called, the Robert S. Kerr Dam or the Markham Ferry Project. The lake and shoreline are privately owned by the (GRDA), which is the same organization that controls Grand Lake. This fact allows for more extensive development of the 200 mile shoreline than lakes controlled by the United States Army Corps of Engineers. Lake Hudson is second in a series of three lakes on the Grand River intended to control flooding, generate electrical power, provide water for drinking, etc., and recreation. The first lake is Grand Lake, then Lake Hudson and Fort Gibson Lake. The estimated monetary benefits of flood prevention total $5,564,000 to 1983.

Fort Gibson Lake was constructed by the United States Army Corps of Engineers in 1952 and is located 40 miles downstream for the Robert S. Kerr Dam, Lake Hudson. The purpose of the lake is to generate electrical power, provide flood control on the Grand River, provide water to several communities (i.e., Muskogee, OK, Wagoner, OK, Fort Gibson, OK) and to provide recreation opportunities. The lake shoreline of 225 miles is controlled by the Corps of Engineers. Estimated monetary benefits from flood prevention to 1983 total $33,617,000.

Spavinaw Lake and Lake Eucha are controlled by the City of Tulsa and are utilized as municipal water supplies for that city. Spavinaw is one of the oldest lakes in the state, it was constructed in 1924 and is located on Spavinaw Creek in Mayes

County, OK. Lake Eucha was constructed in 1952 and is located on Spavinaw Creek in Delaware County, OK.

Public Access Points at Regional Lakes and Other Types of Public Access

The following section presents characteristics of state parks and other types of public access located on the lakes within the eighty kilometer radius of Grand Lake.

Oologah Lake and Other Public Access

There are no state parks located on Oologah lake. Public access is limited to points provided by the Corps of Engineers and the city of Oologah.

Lake Hudson State Parks and Other Public Access

There are two state parks located on Lake Hudson in Mayes County, OK, Salina State Park and Snowdale State Park.

Salina State Park is located in the city of Salina, OK and is limited to day use only. There are twenty-five picnic tables, one group shelter, one comfort station, one sanitary dump station, one playground and one unlighted boat ramp on eighteen acres of state-owned property.

Snowdale State Park has sixty-six picnic tables, one group shelter, sixteen electric hookups and sixty-six unimproved camp sites, one comfort station, one sanitary dump station, one swimming beach, one playground, one volleyball court and one lighted boat ramp on fifteen acres of state- owned property.

Commercial Access Points

There are nine commercial boat launching sites in addition to the two state park sites. A discussion of the location and facilities available at these commercial access points and other relevant businesses around the lake follow:

(1) Hudson Lake Marina - Located off of Boatman Road on the southwest section of the lake, with facilities for gasoline, bait/tackle, food (cafe), purchases, a covered fishing dock, and boat launching.

(2) Lakeland Store - Located on the north side of the Hwy 20 Salina bridge with sales of gasoline and bait/tackle.

(3) Wolf Creek Marina - Located on the west side of Lake Hudson one mile east of the Waterline Road and Hwy 20 intersection, with facilities for boat launching, bait/tackle and gasoline purchase.

(4) Carmacks Lakeside Resort - Located on the west side of the Strang Bridge on Strang Road, with facilities for boat launching, motel room rental, camping, cafe, bait/tackle sales and gasoline sales.

(5) Maple Brook Estates - Located to the west of Langley, OK two miles west of Hwy 82, with facilities for boat launching.

(6) Bird Hollow Park - Located on the south side of the Hwy 82 bridge eight miles south of Langley, OK, with facilities for boat launching and camping.

(7) Hudson Harbor Mobile Home Park - Located on the east side of Lake Hudson one mile west of Strang, OK, with facilities for boat launching, covered fishing dock, RV hookups, camping and a cafe.

(8) Indian Springs Marina - Located on the east side of Lake Hudson near the Spavinaw arm of the lake, with facilities for boat launching, covered fishing dock, motel room rental and bait/tackle/gasoline sales.

(9) Harris Camp Ground - Located two miles north of the Saline Creek bridge on Hwy 82, with facilities for boat launching, RV hookups and camping.

(10) Holiday Village Mobile Home Park - Located two miles east of Hwy 82 on the north side of Saline Creek, with facilities for covered fishing dock and RV hookups.

(11) Holiday Village Restaurant - Located two miles east of Hwy 82 on the north side of Saline Creek, with facilities for cafe and bait/tackle sales.

(12) Jensen's Resort - Located on the south side of the Saline Creek bridge on Hwy 82, with facilities for boat launching, RV hookups and camping.

Fort Gibson Lake State Parks and Other Public Access

There are two state parks located on Fort Gibson Lake, Sequoyah State Park, located in Cherokee County, OK and Sequoyah Bay State Park, located in Wagoner County, OK. Please refer to Figure 9, Fort Gibson Lake for spatial orientation.

Sequoyah State Park has one airport with 3,300 foot runway that is radio equipped and lighted, three hundred and three picnic tables, five group shelters, twenty-eight modern RV sites, one hundred and thirty-three semi-modern RV sites, and one hundred and seventy-eight unimproved camp sites, seven comfort stations with showers, five comfort stations without showers, two sanitary dump stations, one eighteen hole golf course with pro shop, fifty motor carts, twenty pull carts, seven set of rental clubs, seven unlighted boat ramps, one marina with boat rentals, one gas dock, covered and uncovered slips, one snack bar, one covered fishing dock, one swimming pool, one changing house, one swimming beach, two tennis courts, one volleyball court, one playground, one stable with an average of thirty-three horses, one hayride, one pony ride, one covered wagon ride, one stagecoach ride, two hiking trails, one physical fitness trail, one nature center, one paddle boat concession, one service station/grocery store on one hundred and sixty-seven acres of state owned property and two thousand six hundred and eighty- six acres owned by the United States Army Corps of Engineers.

Sequoyah Bay State Park has one hundred and ninety-one picnic tables, twelve individual shelters, three group shelters, sixty-one semi-modern RV sites, one hundred and ten camp sites, four comfort stations with showers (two handicapped equipped), one comfort station without showers, two sanitary dump stations, three lighted boat ramps, one unlighted boat ramp; one marina with eight boathouses, one gas dock, twenty-two open slips, fifty-four covered slips, nine moorings, one concession stand, one heated enclosed fishing dock; one swimming beach, one tennis court, two playgrounds, one snack bar on seventeen acres of state-owned property and two hundred and eighty-six acres of property owned by the United States Army Corps of Engineers.

Commercial and Corps of Engineers Access Points

There are twenty-three commercial and Corps of Engineer boat launching sites in addition to the two state park sites. A discussion of the location and facilities available at these commercial access points and other relevant businesses around the lake follows:

(1) Big Hollow - Operated by the Corps of Engineers and located four miles south of Locust Grove, OK on Hwy 82 and seven miles west, on the northeast shore of Fort Gibson Lake, with facilities for boat launching and public access.

(2) Blue Bill Point - Operated by the Corps of Engineers and located nine miles north of Wagoner, OK just off Hwy 69 on the western shore of Fort Gibson Lake, with facilities for boat launching, camping, drinking water, restrooms, showers, sanitary dump station and electrical outlets.

(3) Chouteau Bend - Operated by the Corps of Engineers and located three miles east on Hwy 33, of Chouteau, OK on the northwestern shore of Fort Gibson Lake, with facilities for boat launching, picnicing, camping, restrooms and concession services.

(4) Damsite - Operated by the Corps of Engineers and located six miles east of Okay, OK on Hwy 251A, with facilities for boat launching, camping, drinking water, restrooms, showers, sanitary dump station and electrical hookups.

(5) Earbob Ferry - Operated by the Corps of Engineers and located four miles south of Locust Grove, OK on Hwy 82 and five miles west, on the northeast shore of Fort Gibson Lake, with facilities for boat launching and public access.

(6) Flat Rock Creek - Operated by the Corps of Engineers and located three miles south of Mazie, OK on Hwy 69 and five miles east, to the western shore of Fort Gibson Lake, with facilities for boat launching, camping, drinking water, restrooms, showers, sanitary dump station, electrical hookups and concession services.

(7) Jackson Bay - Operated by the Corps of Engineers (day use only) and located five miles north of Okay, OK on the southwestern shore of Fort Gibson Lake, with facilities for boat launching, picnicing, restrooms and concession services.

(8) Mallard Bay - Operated by the Corps of Engineers and located three miles east of Okay, OK on the southwestern shore of Fort Gibson Lake, with facilities for

boat launching and public access.

(9) Mazie Landing - Operated by the Corps of Engineers and located two miles north of Mazie, OK on Hwy 69 and three miles east to the northwestern shore of Fort Gibson Lake, with facilities for boat launching, concession services and public access.

(10) Mission Bend - Operated by the Corps of Engineers and located seven miles east of Mazie, OK on the northwestern shore of Fort Gibson Lake, with facilities for boat launching, picnicing, camping (primitive only) and restrooms.

(11) Overlook - Operated by the Corps of Engineers and located just south of the dam with facilities for drinking water and restrooms.

(12) Spring Creek - Operated by the Corps of Engineers and located four miles south of Murphy, OK on the east shore of Fort Gibson Lake, with facilities for boat launching and public access.

(13) Taylor Ferry North - Operated by the Corps of Engineers and located eight miles east of Wagoner, OK on Hwy 51, on the western shore of Fort Gibson Lake, with facilities for boat launching, picnicing, drinking water, group shelter, restrooms, swimming beach, sanitary dump station and concession services.

(14) Taylor Ferry South - Operated by the Corps of Engineers and located eight miles east of Wagoner, OK on Hwy 51, on the western shore of Fort Gibson Lake, with facilities for boat launching, camping, drinking water, restrooms, showers, sanitary dump station and electrical outlets.

(15) Three Finger Bay - Operated by the Corps of Engineers and located five miles east of Mazie, OK on the west shore of Fort Gibson Lake, with facilities for boat launching and public access.

(16) Wagoner Park - Operated by the Corps of Engineers and located five miles east of Wagoner, OK on the west shore of Fort Gibson Lake, with facilities for boat launching, restrooms and public access.

(17) Wahoo Bay - Operated by the Corps of Engineers (day use only) and located seven miles east of Gibson, OK on the west shore of Fort Gibson Lake, with facilities for boat launching, picnicing and restrooms.

(18) Wildwood - Operated by the Corps of Engineers and located six miles west of Hulbert, OK on Hwy 80, on the east shore of Fort Gibson Lake, with facilities for boat launching, picnicing, camping, drinking water, restrooms and sanitary dump station.

(19) Chouteau Bend - Operated by concessionaire and located four miles east of Chouteau, OK on Hwy 33, on the east shore of Fort Gibson Lake, with facilities for boat launching, drinking water, restrooms and concession services.

(20) Damsite - Operated by concessionaire and located at the dam, with facilities for group shelter, restrooms and concession services.

(21) Flat Rock Resort - Operated by concessionaire and located three miles south of Mazie, OK on Hwy 69 and five miles east, to the western shore of Fort Gibson Lake, with facilities for group shelter, restrooms and concession services.

(22) Jackson Bay Marina - Operated by concessionaire and located five miles north of Okay, OK on the southwestern shore of Fort Gibson Lake, with facilities for boat launching, picnicing, camping, restrooms and concession services.

(23) Long Bay Landing - Operated by concessionaire and located six miles east of Wagoner, OK on Hwy 51, on the western shore of Fort Gibson Lake, with facilities for boat launching, picnicing, camping, drinking water, restrooms, concession services and public access point.

(24) Mazie Landing - Operated by concessionaire and located two miles north of Mazie, OK on Hwy 69 and three miles east to the northwestern shore of Fort Gibson Lake, with facilities for picnicing, drinking water, restrooms and concession services.

(25) Taylor Ferry Marina - Operated by concessionaire and located eight miles east of Wagoner, OK on Hwy 51, on the western shore of Fort Gibson Lake, with facilities for boat launching, drinking water, restrooms and concession services.

(26) Whitehorn Cove - Operated by concessionaire and located five miles north of Wagoner, OK on Hwy 69, then six miles east to the western shore of Fort Gibson Lake, with facilities for boat launching, picnicing, camping, drinking water, restrooms and concession services.

(27) Hulbert Landing - Operated by the city of Hulbert, OK and located four miles west of Hulbert, OK on Hwy 51, on the southeastern shore of Fort Gibson Lake, with facilities for public access.

Spavinaw Lake State Park and Other Public Access

Spavinaw State Park is located on Spavinaw Creek below Spavinaw Dam in Mayes County, OK. Please refer to Figure 10, Spavinaw Lake for spatial orientation.

Spavinaw Lake State Park contains twenty-six semi-modern RV sites, thirty unimproved camp sites, one comfort station with showers, one comfort station without showers, one sanitary dump station, one swimming beach, one playground on thirty-five acres of state-owned property.

Other public access is available at Spavinaw Marina on the north side of the dam east of the town of Spavinaw. Visitors can purchase permits, get information, obtain water, cookers, rent boats, motors, use the dock, shelterhouse, picnic tables and launch boats. There is no overnight camping or swimming allowed on Spavinaw Lake.

Lake Eucha State Park and Other Public Access

Upper Spavinaw State Park is located on Lake Eucha in Delaware County, OK. Upper Spavinaw State Park contains fifty-three picnic tables, one group shelter, ten day use only RV parking sites, one comfort station, one swimming pool, one changing house on thirty-one acres of land leased from the City of Tulsa and twenty acres leased from the Jay Chamber of Commerce.

Other public access is available at Eucha Marina at the east end of the lake near the Hwy 59 bridge. Visitors can obtain permits and information, rent boats/motors/tackle, use the restaurant, and launch boats. There is no swimming allowed in Lake Eucha. In addition to this boat launching site there are two other sites, one is near the dam on the west end of the lake at Dunham Hollow boat ramp and the other is on the north side of the lake's middle at Old Eucha Campgrounds, where camp sites are also available. Other camp sites are located east of the Hwy 59 bridge on the south side of the lake and west of the Hwy 59 bridge on the west side of the north side of the lake.

Spavinaw and Eucha lakes are operated by the City of Tulsa as a municipal water supply which requires specific regulations regarding the use of the lakes. The following is a brief summary of these rules:

(1) The instructions of the Lake Patrol must be followed
(2) No garbage, trash, or waste of any kind may be deposited in the lakes
(3) The City of Tulsa is not liable for any injuries or damages
(4) A city boating permit must be in the operator's possession at all times
(5) There must be at least one approved life preserver for each passenger
(6) No sailboats are allowed on the lakes at any time
(7) Row boats have the right-of-way at all times
(8) Cruising boats must stay at least 1000 feet away from any bank or anchored fisherman;
(9) Speeds must not be greater than 18 Mph. within 300 feet of shore
(10) No boats may travel any closer to the dams than the safety cables
(11) Intoxicated persons or intoxicants will not be allowed on the lakes
(12) All boats must be properly licensed by the State of Oklahoma
(13) A city fishing permit must be in fisherman's possession at all times
(14) All fishermen must have a current Oklahoma fishing licence
(15) Oklahoma fishing laws apply in all cases
(16) No wading, swimming or bathing is permitted in the lakes

Attendance Levels at Regional Lake State Parks and Economic Impact on Their Region

Attendance levels vary at the regional lake state park facilities for a variety of reasons. Some of these include: proximity of the state park to a major lake, major roadways, or towns; the type of lake, deep and clear of obstructions or shallow; whether or not the shoreline can be developed; and the type of fishing. There are four major Oklahoma lakes within the eighty kilometer radius of Grand Lake that include State Parks. However, there are no significant lakes within the eighty kilometer radius in Kansas, Missouri or Arkansas.

The four Oklahoma lakes are: Spavinaw, Hudson, Eucha and Fort Gibson. Also there is one major lake that is within the radius that does not include a state park, Oologah Lake, for which the same data is not available. However, attendance figures for 1970 are available and will be included as part of this section. It should be noted that these attendance figures are for those individuals that visit state parks only, which does not represent total attendance for the respective lake. This fact varies from lake to lake do to differing access practices, for example, Lake Eucha has only one access point for boat launching and other water related activities are limited, while Lake Hudson has several public and private boat launching areas and allows for many different types of water sports. This results in considerable variation in the estimates of total visitation and caution should be taken when relying on these figures. Table 24 presents attendance data for several recent years at these sites and for 1970 at Oologah Lake.

Table 24. Annual number of visitors at Oklahoma state parks in vicinity of Grand Lake.

Lake & State Park	Attendance & Year 1987	1988	1990
Hudson			
Snowdale S.P.	147,379	121,613	127,346
Salina S.P.	99,491	76,861	84,395
Total	246,870	198,274	211,741
Eucha			
Upper Spavinaw S.P.	28,732	16,082	22,792
Spavinaw			
Spavinaw S.P.	196,361	200,677	242,941
Fort Gibson			
Sequoyah S.P.	476,862	447,276	397,964
Sequoyah Bay S.P.	307,914	390,754	459,716
Total	784,776	838,030	857,680
Oologah	Attendance for 1970 - 986,500		
Overall Total *	1,256,739	1,253,063	1,334,154
Grand			
Total	919,778	931,357	1,203,320

* Does not include attendance at Oologah Lake or Grand Lake.

The information on visitation was collected by the Oklahoma Department of Tourism and Recreation, Planning and Development Staff during the 1987-1988 Oklahoma State Park Visitor Survey. The data was collected by a random sample method at State Parks in Oklahoma during 1987-1988 by employees of the State Parks and Recreation Service. Individual responses were anonymous and voluntary, if refused the state of origin and a reason for refusal were requested.

The data are for state parks on major lakes within the eighty kilometer radius around Grand Lake and include: Spavinaw State Park; Snowdale State Park; Sequoyah

Bay State Park; Sequoyah State Park; Salina State Park and Upper Spavinaw State Park.

When asked to estimate the expense for a days visit, respondents estimated an average cost per person of $8.79 per day. This figure when multiplied by the attendance figures for 1988 produces a direct economic impact on each lakes region as follows: Spavinaw Lake, Spavinaw State Park attendance of 200,677 represents 1,763,950 dollars; Lake Hudson, Snowdale State Park attendance of 121,613 and Salina State Park attendance of 76,861 represents 1,742,828 dollars; Fort Gibson Lake, Sequoyah Bay State Park attendance of 390,754 and Sequoyah State Park attendance of 447,276 represents 7,366,283 dollars; and Lake Eucha, Upper Spavinaw State Park attendance of 16,082 represents 141,360 dollars.

These estimates do not include trip expenses for individuals who do not visit state parks in each lake's respective region. With this in mind, and the evidence of shoreline development on some of these lakes, the total economic impact of lake usage on each region should be much larger than the impact of state park usage alone. In addition if a multiplier effect is applied to the direct contribution of these monies, the beneficial input would be even greater.

Comparison Discussion of Facilities on Grand Lake and Facilities of Lakes Within Eighty Kilometer Radius

Each of the lakes within the eighty kilometer radius of Grand Lake contribute to local communities in several ways. The most obvious include the generation of electricity, flood control and the availability of water. Additional benefits of each of these lakes involve the contribution of tourism to the local economies. When this is considered there is an obvious difference between the benefits of Grand Lake compared to the other lakes. This is primarily due to the extent of development around Grand Lake compared to the other lakes, which tend to have more controlled shore lines. Other characteristics are also important, the most salient being the size differential between the lakes. Grand Lake is by far the largest in the region. This is not to say that the other regional lakes are not important contributors to the local economies int their respective areas, because they are, but it points to the fact that Grand Lake is the most important lake in the region. With this in mind it is possible to say that if Grand Lake's water quality were to continue to deteriorate, the resulting decline in socioeconomic quality of life in the region would be very strong. On the other hand, if any of the other regional lakes experienced the same occurrence, the results would be far less harmful.

TASK 9: Point Source Pollution

OBJECTIVE: To inventory known point source pollution discharges affecting or which have affected lake water quality over the past 5 years and abatement actions for these discharges.

DISCUSSION: No large city or major industry exists in the Grand Lake watershed. However, several sources of acidic mine wastes exist in both the Neosho and Spring river watersheds. An extensive study has been performed on the quantity of acidic mine waters and associated heavy metal contaminants from Tar Creek, a tributary to Neosho River. Until the recently completed EPA Superfund Diagnostic-Feasibility study of the Galena subsite in Kansas, there had been no evaluations of the quantities of heavy metal contaminants in the Spring River watershed, although several investigators have indicated relative significant contamination.

Extensive development of residential cabins and homes on Grand Lake shoreline may be contributing considerable quantities of nutrients to the lake, due to the practice of using septic tanks for domestic wastedisposal.

SUBTASK 9a: Inventory of Point Source Pollution

METHOD: Consultation with the Oklahoma Water Resources Board, Oklahoma State Department of Health, Oklahoma Corporation Commission, local City/County Health Departments, GRDA, EPA (NPDES permits DMR), State of Kansas, State of Missouri and Grand Lake Resort Owners Association. In addition, the monitoring records of the "Tar Creek" Clean-up Project will be reviewed to determine the quantity of acid mine wastes input to the drainage basin.

DISCUSSION: The total number of point source dischargers in the water shed above Grand Lake illustrate the relative low density of municpalities and industrial development (Table 25). The relative number of dischargers by state also reveals that the relative undeveloped nature of the watershed in Kansas. The

Table 26. Location of Point Source Dischargers by county within Kansas and Arkansas

STATE	COUNTY	MADI	Count of MADI
ARKANSAS	BENTON	MAJOR	1
ARKANSAS	BENTON	MINOR	4
KANSAS	ALLEN	MAJOR	1
KANSAS	ALLEN	MINOR	6
KANSAS	ANDERSON	MINOR	1
KANSAS	CHASE	MINOR	6
KANSAS	CHEROKEE	MAJOR	1
KANSAS	CHEROKEE	MINOR	14
KANSAS	COFFEY	MAJOR	1
KANSAS	COFFEY	MINOR	7
KANSAS	CRAWFORD	MAJOR	1
KANSAS	CRAWFORD	MINOR	19
KANSAS	LABETTE	MAJOR	2
KANSAS	LABETTE	MINOR	15
KANSAS	LYON	MAJOR	2
KANSAS	LYON	MINOR	19
KANSAS	MARION	MINOR	7
KANSAS	MCPHERSON	MINOR	1
KANSAS	MORRIS	MINOR	7
KANSAS	NEOSHO	MAJOR	1
KANSAS	NEOSHO	MINOR	14
KANSAS	WABAUNSEE	MINOR	1
KANSAS	WOODSON	MINOR	5

Table 27. Location of Point Source Dischargers by Counties in Missouri and Oklahoma.

STATE	COUNTY	MADI	Count of MADI
MISSOURI	BARRY	MAJOR	1
MISSOURI	BARRY	MINOR	2
MISSOURI	BARTON	MINOR	8
MISSOURI	JASPER	MAJOR	8
MISSOURI	JASPER	MINOR	42
MISSOURI	LAWRENCE	MAJOR	3
MISSOURI	LAWRENCE	MINOR	13
MISSOURI	MCDONALD	MAJOR	1
MISSOURI	MCDONALD	MINOR	12
MISSOURI	NEWTON	MAJOR	2
MISSOURI	NEWTON	MINOR	11
OKLAHOMA	CRAIG	MINOR	2
OKLAHOMA	DELAWARE	MINOR	12
OKLAHOMA	OTTAWA	MAJOR	2
OKLAHOMA	OTTAWA	MINOR	18

Table 28. Oklahoma municipal POTW dischargers in vicinity of Grand Lake.

Facility	Receiving Stream	Discharge liters /DAY	Total PO4 kg/day	Total nitrogen kg/day
AFTON	CREEK	454545	1.31	6.43
BEACON HILL	GRAND LAKE	ND	ND	ND
COMMERCE	TAR CREEK	757576	3.87	17.71
FAIRLAND LAGOON	HUDSON CRK TRIB	268939	1.4	4.14
GRAND POINT	KETCHUM COVE	ND	ND	ND
GROVE	GRAND LAKE	924242	12.06	33.06
JAY	DROWNING C. TRIB	4166667	21.92	127
MIAMI 1	NEOSHO R	4621212	26.71	90.07
MIAMI 2	TAR CRK	1136364	6.2	24.07
MIAMI 3	NEOSHO R	265152	1.07	2.51
PICHER	LYTLE C. TRIB	909090	2.08	7.22
PORT DUNCAN 1	GRAND LAKE	ND	ND	ND
PORT DUNCAN 2	GRAND LAKE	ND	ND	ND
QUAPAW	GRAND R. TRIB	356060	4	14.55
SENECA INDIAN SCHOOL	LOST CREEK	ND	ND	ND
SECECA MO	LOST CREEK	757576	5.28	8.48
SPINAKER POINT	DUCK CREEK	ND	ND	ND

TASK 10: Land Use

OBJECTIVE: To describe land use practices in the lake watershed as a percentage of the whole and discussion of the amount of nonpoint pollutant loading produced by each category.

DISCUSSION: The watershed above Grand Lake is primarily used for cattle grazing, hay production, and some intensive agricultural practices (Table 29 - Table 32). Extensive mining operations and disposal of wastes from the mines in surface chat piles may be contributing some trace metal contamination to the surface water runoff.

Agricultural Acitivities

Agricultural activities occur on approximately 60% of the land area of the Grand Lake drianage basin. Most of the agriculture activities are relatively non-intensive, i.e., wheat and corn production, hay production, and range cattle. However, there have been some intensive type of animal rearing/feeding operations develop within the last few years. The poultry market has attracted many farmers to switch to more intensive broiler rearing facilities. These facilities often concentrate thousands of broilers within a few hundred cubic feet of barn. As a result, considerable quantities of poultry manure are produced within short periods of time.

The farmers have attempted to spread the poultry manure and associated wheat straw, called poultry litter, on their hay meadows or pastures to increase forage for cattle grazing operations. However, the quantities of litter produced quickly exceed the assimilation capacity of the soil microbes or vegetation. As a result, considerable quantities of phosphorus and nitrogen are lost to surface water runoff during rainfall events. In addition, continued application of high levels of poultry litter on some types of soils which do not retain moisture, results in high concentrations of nitrates in the shallow groundwater.

The development of poultry processing houses for slaughtering and packaging poultry products has also increased potential for increased waste loads upon surface receiving streams.

Lakeside Recreation

Numerous lakeside resorts, including the Shangri La Lodge, Oklahoma's leading privately-owned resort, offer overnight accommodations and dining facilities. The lake's five large publicly-owned recreation areas provide facilities for numerous uses: boating , fishing, swimming, camping (with trailer facilities) picnicking, and playgrounds (Task 4, ?). Grand Lake is heavily used by the local communities of Miami, Vinita and Tulsa.

Another land use practice, which has the potential for relatively large impact, is the development of lake shore residential areas. Although, the total percentage of land would be small, the impact is large due to the proximity to the lake. Grand Lake was built for flood control and hydro-electric generating facility by a state agency, the Grand River Dam Authority (GRDA). GRDA allowed construction of lake shore residential areas within a few feet of the flood pool elevation. In the early years, many residential homes were constructed without regard to either septic tank-lateral line or other type of domestic waste treatment systems. As a result, 8,093 homes have been built within 500 feet of the lake perimeter at flood pool elevation and 1273 between 500 feet and 1/4 mile zone. Based upon the conservative estimates of Chapra and Reckhow (1983) these residential units could contribute a low of 1,396 up to a high of 4,656 kg/year of phosphorus to the lake. These calculations were based upon the assumptions that an average of 3.5 people lived in each residence and stayed at the lakeside cabins an average of 60 days/year.

Mining Operations

Mining operations have been a major activity in the Grand Lake drainage basin for many years. With the close of World War II, mining activity in the Tri-State Mining District made up of Oklahoma, Kansas and Missouri gradually ceased. Most of the mines stopped operation in 1969-70, due to a drop in price of lead and zinc in 1968 and to the increased costs of pumping water out of the mines and complying with wastewater regulations.

The abandoned mine shafts filled with water which reacted with iron pyritic minerals to form an acidic solution, with pH values ranging from 3 to 5 [1]. Eventually, the acidic water, laden with heavy metals in solution, flowed out of the mines and reached the surface where it flowed into a tributary of Tar Creek. In 1981, the Tar Creek site was described as one of the nation's most severely polluted sites. The remedial program under Superfund lasted six years and consisted of efforts to plug and cap abandoned water wells. Diversion of flows around sinkholes and mine cave-ins was also part of the clean up.

A similar super fund cleanup program was initiated at Galena, Kansas on the Spring River.

Table 29. Summary of major land use cagetories in Mayes County, Oklahoma (SCS, 1991).

No.	Mayes County Land Use Category Name	Acres
1	rangeland - open grasslands	47671
2	pastureland	166624
3	forest land - bottomland hardwoods	12464
4	cropland	39477
5	urban ranchettes - (house & lot 2-20 acres)	16467
6	post oak and blackjack oak	59096
7	strip mines - unreclaimed (fair to good veg cover)	109
8	pastureland - brushy (>20% canopy)	16734
9	rangeland - persimmon, winged elm, sumac	10764
10	forestland - oak, hickory, etc (>70% decid.)	24275
11	rangeland - blackjack-postoak brush,	1977
12	rangeland - cottonwood, elm, hackberry, etc	8697
13	highways - multi-lane highways (4 or more)	2135
14	quarries and gravel pits - (>5 ac)	1206
15	water	17475
16	urban and builtup land	6820
17	farmsteads - (>5 ac)	455
18	rangeland - upland shrubs	1453
19	cropland - orchards, groves, etc	208
20	sewage lagoon	326
21	cropland - irrigated	385
22	rangeland - juniper, eastern red cedar	494
23	landfill - active	178
24	forest land - pine-oak (n[illegible]d forest)	1472
25	confined feeding operations	49

Table 30. Summary of land use categories in Ottawa County, Oklahoma (SCS, 1991).

No.	Ottawa County Land Use Category Name	Acres
1	rangeland - open grasslands	12958
2	pastureland	128680
3	forest land - bottomland hardwoods	5377
4	cropland	67518
5	urban ranchettes - (house & lot 2-20 acres)	1048
6	pecan groves and pastureland	3351
7	strip mines - unreclaimed (fair to good veg cover)	40
8	pastureland - brushy (>20% canopy)	17000
9	rangeland - persimmon, winged elm, sumac	1067
10	forestland - oak, hickory, etc (>70% decid.)	41622
11	rangeland - blackjack-postoak brush,	30
12	rangeland - cottonwood, elm, hackberry, etc	8697
13	highways - multi-lane highways (4 or more)	2224
14	quarries and gravel pits - (>5 ac)	79
15	water	10971
16	urban and builtup land	9212
17	rangeland - upland shrubs	128
18	lead and zinc mine spoils	4912
19	rangeland - sand sagebrush	119
20	landfill - urban and rural (active)	89
21	forest land - pine-oak (mixed forest)	1472
22	confined feeding opera[illegible]s	49

Table 31. Summary of land use categories for Craig County, Oklahoma (SCS, 1991).

No.	Craig County Land Use Category Name	Acres
1	rangeland - open grasslands	161949
2	pastureland	27378
3	bottom woodlands and rangeland	613
4	bottom woodlands and pastureland	1848
5	urban ranchettes - (house & lot 2-20 acres)	119
6	cropland	72726
7	strip mines - reclaimed (smoothed & reseeded)	15557
8	strip mines - unreclaimed	4102
8	strip mines - active	30
9	pastureland - (bermudagrass)	151373
10	rangeland - persimmon, winged elm, sumac	10339
11	forestland - oak, hickory, etc (>70% decid.)	34633
12	rangeland - upland shrubs	1087
13	pecans and pasturelands	781
14	highways - multi-lane highways (4 or more)	336
15	quarries and gravel pits - (>5 ac)	49
16	water	662
17	urban and builtup land	3519
18	farmsteads - (>5 ac)	49
19	rangeland - upland shrubs	1087
20	cropland - orchards, groves, etc	20
21	rangeland - persimmon, w. elm (HD >25 plts/ac)	662

Table 32. Summary of major land use categories for Delaware County, Oklahoma (SCS, 1991).

No.	Delaware County Land Use Category Name	Acres
1	rangeland - open grasslands	1295
2	pastureland	196573
3	cropland - orchards, groves, etc	217
4	cropland	12611
5	urban ranchettes - (house & lot 2-20 acres)	59
6	farmsteads - (>5 acres)	40
7	cemetery (rural)	49
8	forestland - oak, hickory, etc (>70% decid.)	227391
9	rangeland - blackjack-postoak brush,	12078
10	quarries and gravel pits - (>5 ac)	10
11	water	33774
12	urban and builtup land	23445
13	landfill - (active)	10
	TOTALS	507552

TASK 11: Limnological Data

OBJECTIVE: To compile and analyze the historical baseline limnological data and to measure 1 year of current limnological data.

DISCUSSION: Grand Lake is a valuable resource for the State of Oklahoma. In addition to the hydroelectric power generation, flood control, and water supply, it also provides a valuable recreational resource for Oklahomans and residents from Kansas, Missouri, and Arkansas.

The major problems existing in Grand Lake include contamination by lead/zinc mining wastes and nutrient enrichment. The heavy metal contamination results from flooding of abandoned lead/zinc mines and subsequent contamination of surface streams. The nutrient enrichment results from anthropogenic inputs from extensive development along shoreline and use of septic fields in a highly fractured limestone and from upstream municipal public owned treatment systems and runoff from agricultural activities in the basin.

Historical Baseline Limnological Data

Sources of Data.

Several projects have been conducted in the past 5 years in conjunction with the Tar Creek investigation of acid mine waste contamination of surface waters. These reports will provide a baseline for estimating the heavy metal contamination. In addition, surveys were conducted of general limnological parameters in Grand Lake prior to the Tar Creek project.

The EPA national eutrophication survey included Grand Lake as one of the lakes sampled in Oklahoma. In addition, one M.S. thesis project has been performed on metal contamination upon upper end of Grand Lake (McCormick, 1985).

As part of the requirements for renewal of the Federal Energy Regulatory Commission permit for hydroelectric generation, the GRDA is currently conducting a survey of general limnological parameters in Grand Lake. We propose to compliment the on-going

GRDA study by focusing on other parameters.

Statistical Methods

Nonparametric statistical techniques are useful in detecting for the presence of trends in a water quality time series. These tests are particularly effective when used to analyze water quality data which are likely to contain missing observations, observations which are non-normally distributed, observations reported as below the detection limit, and observations from systems impacted by man's activities. The historical water quality data sets from both the Neosho River and Spring River possess these characteristics, thus nonparametric statistics will be used to test for the presence of trends for specified nutrients and heavy metals.

Using the software package WQSTAT II developed by Colorado State University (Phillips et al., 1989), the nonparametric tests to be employed are Kendall's Tau Test which checks for a correlation between ranks of data and time, the Seasonal Kendall Test which computes the Kendall Tau Test statistics for each season (month or quarter) and combines them into an overall statistic, and the Seasonal Kendall Sen Slope Estimator which will indicate the magnitude and direction of the trend. The Kendall Tau and the Seasonal Kendall tests are used to test the null hypothesis of no temporal trend in the selected data against a two-sided alternative of either increasing or decreasing trend. Both tests are computed at the 95, 90, and 80 percent confidence levels, which are highly significant for trend, significant for trend, and weakly significant for trend, respectively (Loftis et al, 1989).

Data were collected from the USGS HYDRODATA database for three stations on the Neosho River, four tributary stations of the Spring River, and two stations on the Spring River (Table 33 -Table 38, Figure 12). The stations on the Neosho River include USGS 07182510, USGS 07183500, and USGS 07185000. The stations on the Spring River include USGS 07188000 and USGS 07186000, with tributary stations USGS 07186040 on Cow Creek, USGS 07187000 on Shoal Creek, as well as USGS 07186480 and USGS 07186400 on Center Creek.

The time series of average quarterly total phosphorous and nitrite plus nitrate concentrations (sampling dates illustrated in Table 34) at each of the stations on the two rivers were tested for significant temporal trends. The data for those analyses are presented in Table 35 and Table 36 respectively.

Using Kendall's Tau on the Neosho River, USGS 07183500 and USGS 07185000 showed positive trends in total phosphorous concentration significant at the 90% confidence level (Table 39). The remaining station, USGS 07182510 showed no apparent significant trend in total phosphorous concentration over the period of record.

For the Seasonal Kendall Test on total phosphorous concentrations in the Neosho River, the results were roughly the same with confidence evels increasing. The two stations which showed a significant positive trend for total phosphorous using the Kendall Tau Test, showed a highly significant positive trend in total phosphorous concentrations at the 95% confidence level.

The Seasonal Kendall Sen Slope Estimate indicates the direction and magnitude of the observed temporal trends. All three stations on the Neosho River showed positive slopes indicating increasing total phosphorous concentrations over the period of record (Figure 13 - Figure 25).

Temporal trend test results for total phosphorous concentrations on the Spring River are found in Table 39. Using Kendall's Tau, temporal trend test results for total phosphorous concentrations indicated no apparent significant trend in total phosphorous concentrations for the two stations on the main stem of the Spring River over the period of record. The stations on Cow Creek and Shoal Creek also showed no apparent significant trend in total phosphorous concentrations over the period of record. The stations located on Center Creek showed negative trends in total phosphorous concentrations highly significant at the 95% confidence level.

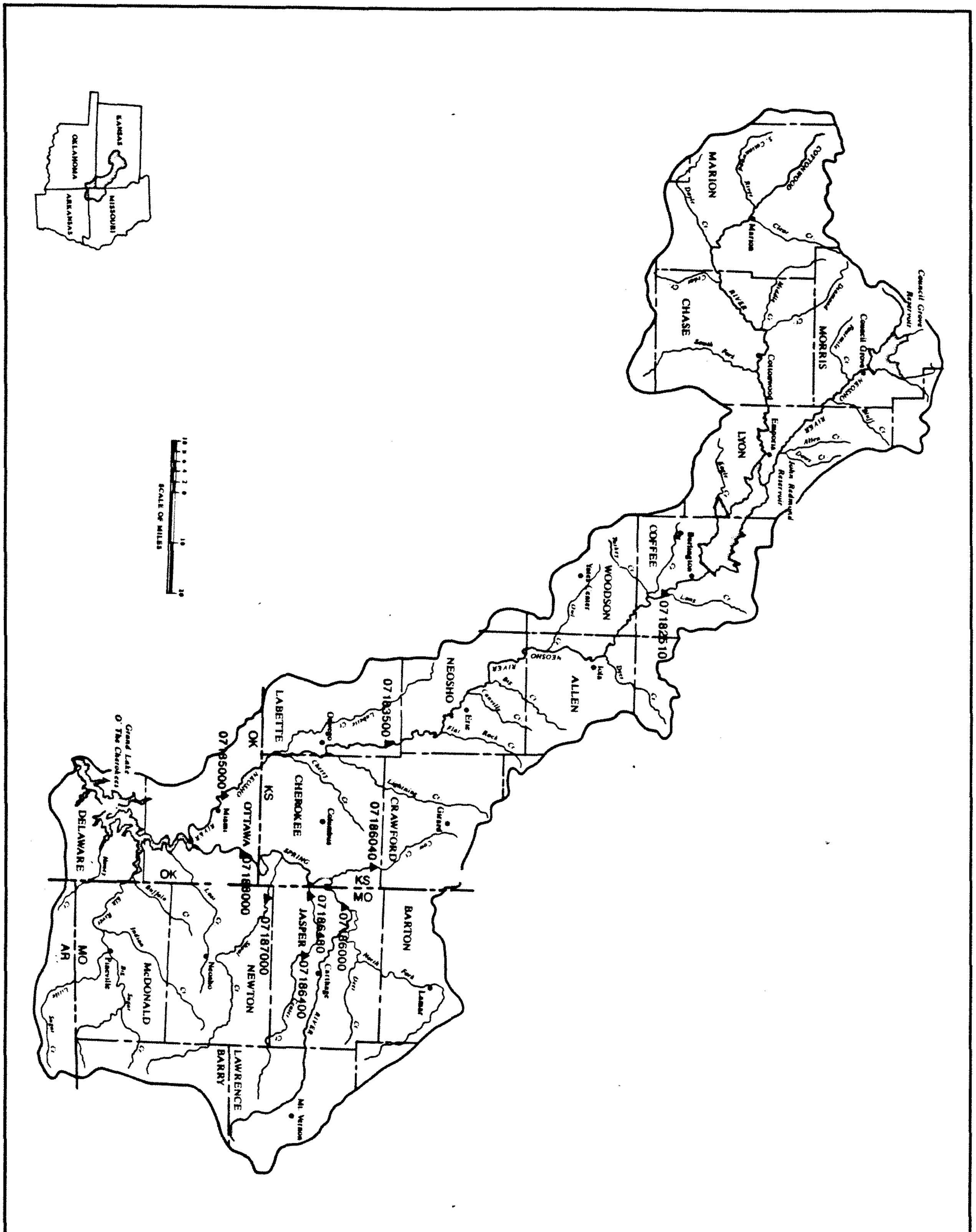


Figure 12. Neosho and Spring River Basin Water Quality Monitoring Stations.

Table 33. Neosho and Spring River basin water quality monitoring stations.

Station ID	Location Description	Legal Location	Latitude & Longitude	River Mile
Spring River Stations				
USGS 07186400	Center Creek, 3 mi. E of Carterville	SEC24, T28N, R32W, Jasper, Co., MO	37 08 26 94 22 57	17 mi. >conflu ence
USGS 07186480	Center Creek, 1 mi. S of Smithville	SEC14, T28N, R34W, Jasper Co., MO	37 09 20 94 36 10	
USGS 07187000	Shoal Creek, 0.5 mi. S of Joplin	SEC34, T27N, R33W, Newton Co., MO	37 01 23 94 30 58	13.2 mi. >confl
USGS 07186040	Cow Creek, 5 mi. E of Weir	SEC33, T31S, R25E, Cherokee Co., KS	37 18 35 94 40 48	1.5
USGS 07186000	1.5 mi. E of Waco	SEC18, T29N, R33W, Jasper Co., MO	37 14 44 94 33 58	47.6
USGS 07188000	3.0 mi. SE of Quapaw	SEC5, T28N, R24E, Ottawa Co., OK	36 56 04 94 44 45	13.9
Neosho River Stations				
USGS 07182510	0.3 mi. upstream from Rock Creek	SEC26, T21S, R15E, Coffey Co,. KS	38 11 40 95 44 10	338.4
USGS 07183500	8 mi. SE of Parsons	SEC33, T31S, R21E, Labette Co., KS	37 18 39 95 06 37	201.4
USGS 07185000	Co. rd. brdg. 4.5 mi. W of Commerce	SEC5, T28N, R22E, Ottawa Co., OK	36 55 43 94 57 26	153.4

Table 34. Period of record of data sets for monitoring stations in the Neosho and Spring Rivers.

Station	Total P (as P)	NO_2+NO_3 (as N)
Neosho River		
USGS 07182510	71* - 75*	
USGS 07183500	71* - 87*	79* - 81*
USGS 07185000	69* - 80*	77* - 80*
Spring River		
USGS 07186480	69* - 88	73 - 88
USGS 07186400	69* - 88	73* - 88
USGS 07187000	79 - 82	79 - 82
USGS 07186040	77* - 81*	
USGS 07186000	69* - 81	73* - 81
USGS 07188000	75* - 80	77* - 80

* Indicates partial data for that water year.

Table 35. Summary statistics and quartile distribution of total phosphorus (as P) (mg/l) for Neosho and Spring Rivers, total period of record.

Station ID	N	Min.	25%	Median	75%	Max.	Mean	SD
Neosho River								
USGS 07182510	22	.03	.05	.11	.16	4.6	.36	.982
USGS 07183500	101	.02	.0975	.14	.1925	1.2	.167	.149
USGS 07185000	80	.01	.08	.1175	.2075	8.99	.226	.995
Spring River								
USGS 07186000	63	.02	.13	.19	.28	1.3	.236	.194
USGS 07188000	45	.12	.1865	.262	.3575	.795	.291	.141
USGS 07186040	26	.02	.2	.46	1.2	7.59	1.221	1.856
USGS 07186480	165	.02	.09	.14	.22	1.4	..190	.176
USGS 07186400	186	.02	.09	.12	.3	3.0	.263	.371
USGS 07187000	23	.02	.04	.05	.07	.12	.055	.029

Table 36. Summary statistics and quartile distribution of nitrate + nitrite (mg/l as N) for the Neosho and Spring Rivers, total period of record.

Station ID	N	Min.	25%	Median	75%	Max.	Mean	SD
Neosho River								
USGS 07183500	27	.01	.0375	.12	.8625	1.6	.44	.492
USGS 07185000	22	.01	.475	.6	.925	1.9	.718	.474
Spring River								
USGS 07186000	39	.01	1.2	1.6	1.9	2.6	1.449	.644
USGS 07188000	23	.6	2.3	2.8	3.0	4.6	2.726	.822
USGS 07186480	141	.03	3.765	4.7	6.9	18.0	5.494	2.994
USGS 07186400	138	.1	3.775	4.8	7.9	30.0	6.058	3.814
USGS 07187000	21	1.1	1.45	1.8	1.88	3.1	1.788	.442

Table 37. Summary statistics and quartile distribution of dissolved phosphorus (as mg/l P) in Neosho and Spring River, for total period of record.

Station ID	N	Min.	25%	Median	75%	Max.	Mean	SD
Neosho River								
USGS 07183500	54	.01	.04	.08	.13	.28	.09	.06
Spring River								
USGS 07186000	33	.02	.0655	.1	.14	.6	.125	.11
USGS 07186480	35	.04	.12	.19	.28	1.3	.243	.227
USGS 07186400	78	.06	.1	.18	.32	2.2	.286	.318

Table 38. Summary statistics and quartile distribution of total nitrogen (mg/l as N) for Neosho and Spring Rivers.

Station ID	N	Min.	25%	Median	75%	Max.	Mean	SD
Neosho River								
USGS 07183500	27	.33	.84	1.4	2.3	3.3	1.646	.827
USGS 07185000	31	.55	1.54	2.05	3.1	5.43	2.281	1.171
Spring River								
USGS 07186000	12	.25	1.65	2.25	2.475	2.6	1.947	.786
USGS 07188000	33	.6	2.225	3.92	4.51	6.5	3.54	1.415
USGS 07186480	12	.67	3.05	4.25	5.725	10.0	4.522	2.31
USGS 07186400	41	.81	4.225	5.05	8.575	32.0	6.85	5.303

Table 39. Trend tests for total phosphorus (as P) in Neosho and Spring River basins.

Station	Kendall Tau Test Statistic	Seasonal Kendall Test Statistic	Seasonal Kendall Sen Slope Estimate (mg/l/yr)
Neosho River			
USGS 07182510	0.765	0.849	0.02250
USGS 07183500	1.724**	2.049***	0.00333
USGS 07185000	1.820**	2.767***	0.01593
Spring River			
USGS 07186000	-0.542	0.766	0.00517
USGS 07188000	-0.865	-0.765	-0.03367
USGS 07186040	0.343	0.970	0.25778
USGS 07186480	-6.978***	-7.058***	-0.01240
USGS 07186400	-6.440***	-6.880***	-0.01730
USGS 07187000	0.000	0.000	0.00250

* Significant at the 80% confidence level

** Significant at the 90% confidence level

*** Significant at the 95% confidence level

The Seasonal Kendall tests, like the Kendall Tau, also indicated no apparent significant trend at any of the stations reporting in the Spring River basin.

The Seasonal Kendall Sen Slope Estimate for USGS 07186000 showed a downward trend of -0.03200 mg/l/yr while USGS 07188000 showed an upward trend of 0.28333 mg/l/yr. Stations on Center Creek were also divided with USGS 07186480 showing a downward trend of -0.03472 mg/l/yr and USGS 07186400 showing an upward trend of 0.00519 mg/l/yr.

Overall, the results of the trend tests on the Neosho River indicate that total phosphorous levels have been increasing over time. This is evident at USGS 07183500 at Parsons, Kansas and at USGS 07185000 at Commerce, Oklahoma. However, the trend tests for nitrite plus nitrate levels have indicated no apparent significant increasing trend over time for the Neosho River. For the Spring River, trend tests on both total phosphorous and nitrite plus nitrate indicate no apparent significant upward trend in the nutrient levels over time.

Consideration of trends in heavy metal concentrations, specifically zinc and lead is important due to the presence of acid mine drainage into both rivers. The nonparametric tests employed for nutrient trend analysis will also be used to evaluate the temporal trends over the period of record for total zinc concentrations and total lead concentrations in both the Neosho River and the Spring River. Stations from which data were collected for the nutrient trend analysis will remain the same for metals trend analysis.

The time series of average quarterly total zinc concentrations at stations reporting on the Neosho River and the Spring River were tested for significant temporal trends. Results of the Kendall Tau, Seasonal Kendall, and Seasonal Kendall Sen Slope Estimates are shown for the Neosho River and the Spring River in Table 39

Kendall Tau tests on historic data sets for the Neosho River show only a significant downward trend in total zinc concentration. USGS 07183500 showed a negative trend in total zinc concentration significant at the 90% confidence level. No apparent significant trend was shown at USGS 07185000 for total zinc concentration over the period of record.

Trend results using the Seasonal Kendall test on total zinc concentrations at USGS 07183500 differed slightly from the Kendall Tau test results. Using the Seasonal Kendall, no apparent significant trend was shown at USGS 07183500 (Parsons, Kansas), whereas a significant downward trend was indicated previously. No apparent significant trend in total zinc concentration was again shown for USGS 07185000 (Commerce, Oklahoma).

Seasonal Kendall Sen Slope Estimates for total zinc trends indicate the direction and magnitude of the observed trends. A negative slope of -10.0 ug/l/yr, indicating decreasing total zinc concentrations over the period of record was observed at USGS 07183500. At USGS 07185000, a nonsignificant upward slope of 1.5 ug/l/yr was observed.

For the Kendall Tau test on the Spring River, one tributary station (Cow Creek, KS) showed a positive trend in total zinc concentration significant at the 90% confidence level. The two tributary stations on Center Creek, USGS 07186400 and USGS 07186480, showed decreasing trends highly significant at the 95% confidence level and highly significant at the 90% confidence level, respectively. The remaining two stations on the main stem of the Spring River showed no apparent significant trend in total zinc concentration over the period of record.

Using the Seasonal Kendall test, trend results and significance levels remained the same as the Kendall Tau test for all stations.

The Seasonal Sen Slope Estimates for total zinc concentration trends ranged from a positive slope of 30.476 ug/l/yr at USGS 07186040 to a negative slope of -12.33 ug/l/yr at USGS 07186480. Three positive sloped were observed. USGS 07186040 (Cow Creek, Weir, KS) was the only station with a positive slope corresponding to a significant upward trend using both the Kendall Tau and Seasonal Kendall tests. The two stations on the mainstem of the river showed nonsignificant upward trend slopes of 30.375 ug/l/yr (USGS 07186000) and 16.833 ug/l/yr (USGS 07188000). At tributary stations on Center Creek, negative slopes were observed for USGS 07186400 (-4.0 ug/l/yr) corresponding with a highly significant downward trend, and for USGS 07186480 (-12.333 ug/l/yr) corresponding with a significant downward trend.

Stations reporting on the Neosho River and Spring River were tested for significant temporal trends in total lead concentrations. Results of the Kendall Tau test, Seasonal Kendall test, and Seasonal Kendall Sen Slope Estimates on time series of average quarterly total lead concentrations in both the Neosho and Spring Rivers are reported in Table 39

Kendall Tau test results for total lead concentrations on the Neosho River show both a weakly significant upward trend and a highly significant downward trend. USGS 07183500 shows a highly significant decreasing trend in total lead concentration at the 95% confidence level. Downstream at USGS 07185000, a weakly significant increasing trend in total lead concentration is apparent at the 80% confidence level.

Results of the Seasonal Kendall tests for total lead trends show only slight variation from the results obtained with the Kendall Tau test. USGS 07183500 which previously showed a highly significant decreasing trend, showed a weakly significant decreasing trend significant at the 80% confidence level with the Seasonal Kendall test. Trend results using the Seasonal Kendall test for USGS 07185000 were identical to the results obtained using Kendall's Tau.

Seasonal Kendall Sen Slope Estimates showed an upward slope of 1.875 ug/l/yr for USGS 07185000 which is correlated with a weakly significant increasing trend. For USGS 07183500, a downward slope of -2.0 ug/l/yr is correlated with a weakly significant (Seasonal Kendall) and highly significant (Kendall Tau) decreasing trend in total lead concentration.

For the Kendall Tau test on total lead concentrations in the Spring River, mainstem station USGS 07186000 showed a highly significant decreasing trend at the 95% confidence level. The other reporting mainstem station, USGS 07188000 showed a nonsignificant upward trend. Tributary stations USGS 07186400 and USGS 01786480 on Center Creek showed a highly significant decreasing trend and a weakly significant decreasing trend, respectively. The remaining station on Cow Creek, USGS 07186040, showed no trend.

The Seasonal Kendall test elicited slightly different results than the Kendall Tau. For USGS 07186000, the significance level for downward trend in total lead concentration decreased from a highly significant trend at the 95% confidence level using Kendall's Tau to a significant trend at the 90% confidence level. Tributary station USGS 07186400 which showed a downward trend highly significant at the 95% confidence level, indicated only a significant downward trend at the 90% confidence level using the Seasonal Kendall test. However, USGS 07186480 had significance level for a decreasing trend in total lead increase from weakly significant to highly significant at the 95% confidence level using the Seasonal Kendall. The remaining stations showed a nonsignificant downward trend (USGS 07186040) and no trend (USGS 07188000).

The Seasonal Sen Slope Estimates for four of the five stations in the Spring River drainage basin show decreasing slopes which range from -7.50 ug/l/yr to -0.20 ug/l/yr. The remaining slope estimate is 0.00 ug/l/yr (USGS 07188000) indicating no slope. USGS 07186000 indicated a downward slope of -5.00417 ug/l/yr correlated with a highly significant (Kendall's Tau) and significant (Seasonal Kendall) decreasing trend in total lead concentrations. A slope of -7.50 ug/l/yr is associated with a nonsignificant downward slope at USGS 07186040. The two USGS stations on Center Creek both showed downward slopes correlated with decreasing trends in total lead concentrations at various significance levels.

The trend tests on metals in the Neosho River provide somewhat confusing results. Indicating that total lead concentrations at USGS 07183500, Parsons, Kansas have been decreasing over time, the trend tests also indicate that downstream at USGS 07185000, Commerce, Oklahoma, total lead concentrations have been increasing over time. For total zinc concentrations in the Neosho River, a decreasing rather than an increasing trend is evident. Trend tests on the Spring River are less complex. For the two tributary stations on Center Creek there is a decreasing trend in both total lead concentrations and total zinc concentrations over time. USGS 07186040 on Cow Creek near Weir, Kansas shows only a significant increasing trend in total zinc levels. The Spring River mainstem stations at Waco, Missouri and Quapaw, Oklahoma show no apparent increasing trend in total lead levels as well as no apparent significant increasing trend in total zinc levels over time.

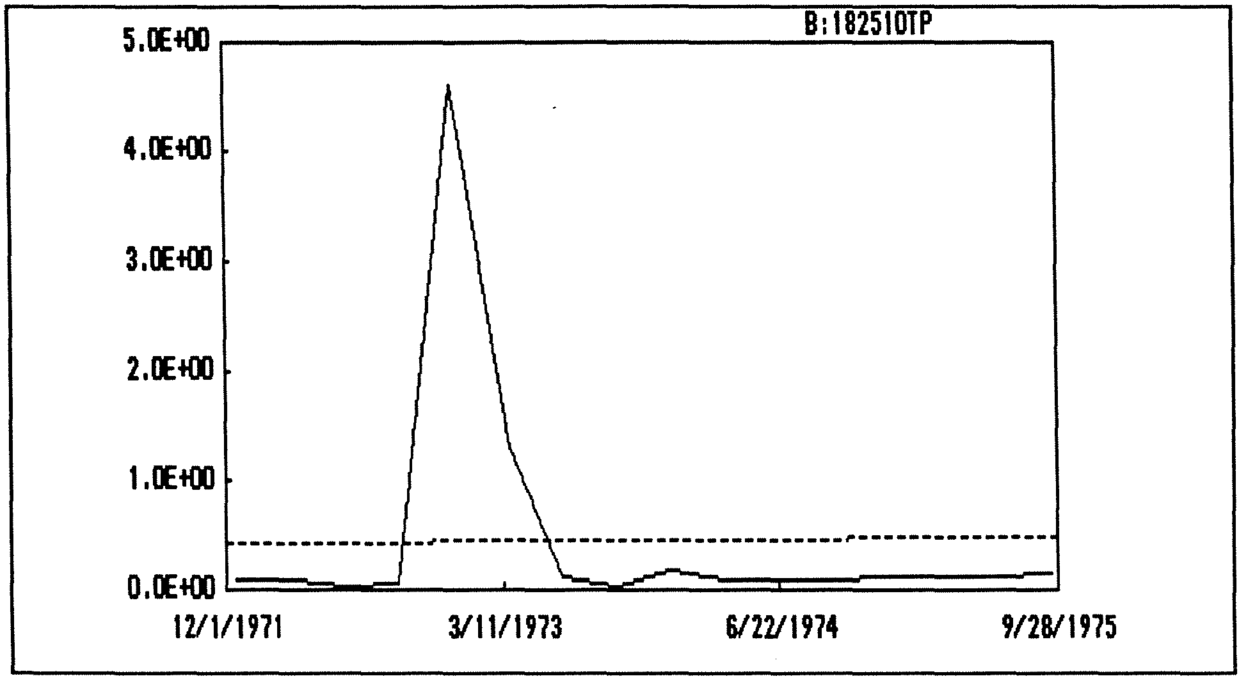


Figure 13. Trend line of quarterly average total phosphorous concentration (as mg/l P) at USGS 07182510 on the Neosho River. Slope estimate = 0.02250 mg/l/yr.

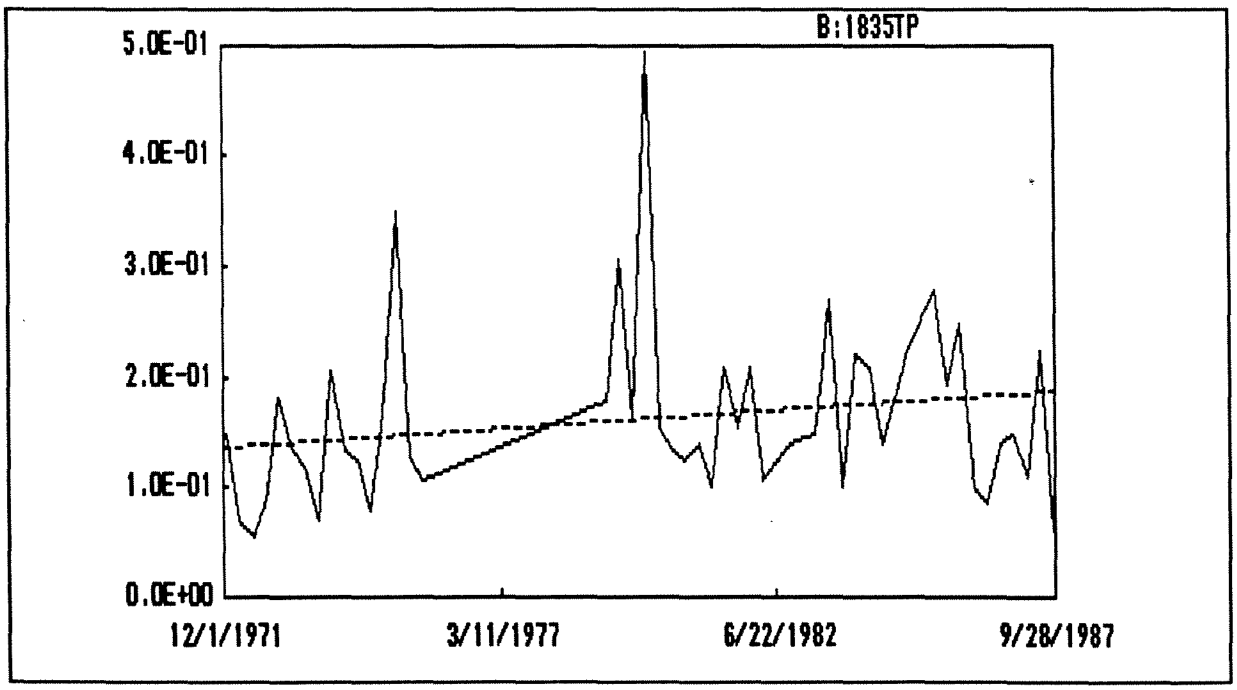


Figure 14. Trend line of quarterly average total phosphorous concentration (as mg/l P) at USGS 07183500 on the Neosho River. Slope estimate = 0.00333 mg/l/yr.

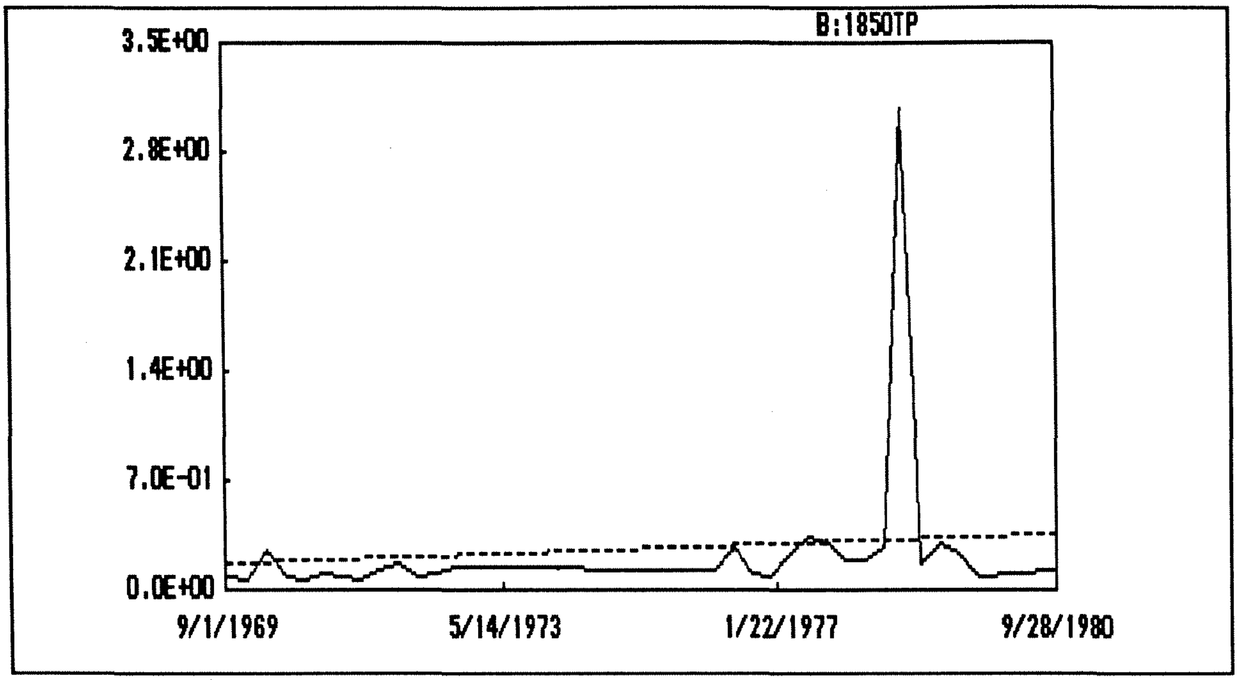


Figure 15. Trend line of quarterly average total phosphorous concentrations (mg/l as P) at USGS 07185000 on the Neosho River. Slope estimate = 0.01593 mg/l/yr.

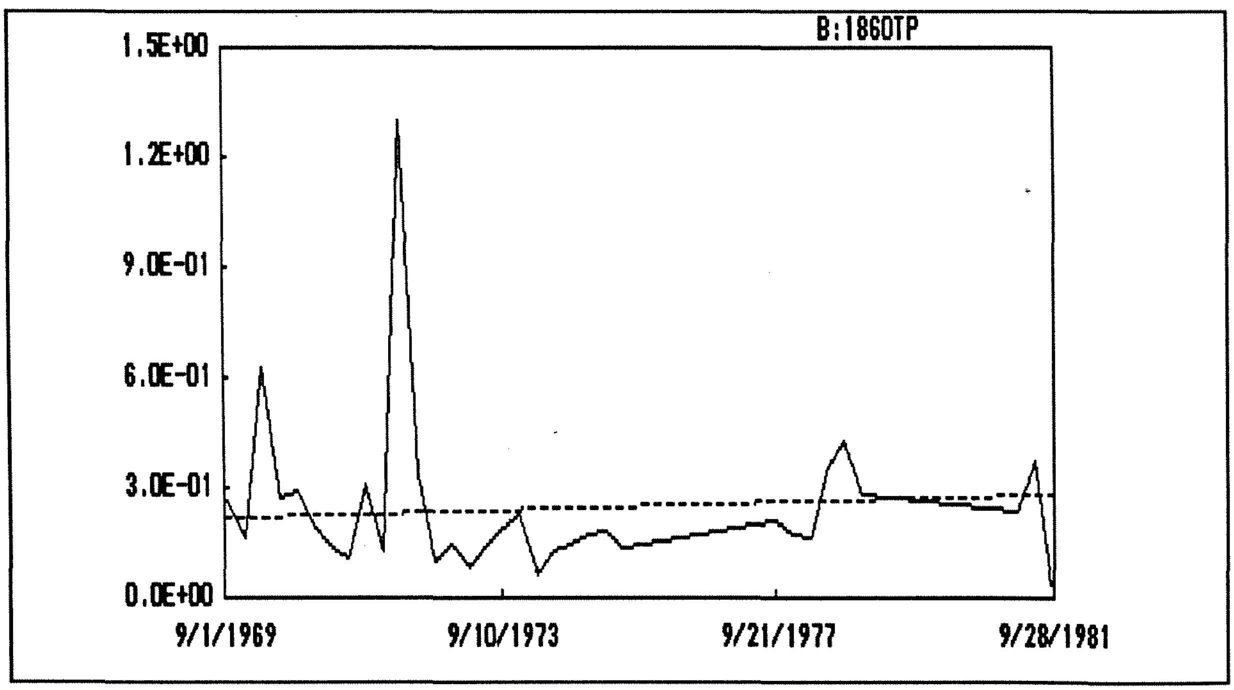


Figure 16. Trend line of quarterly average total phosphorous concentration (mg/l as P) at USGS 07186000 on the Spring River. Slope estimate = 0.00517 mg/l/yr.

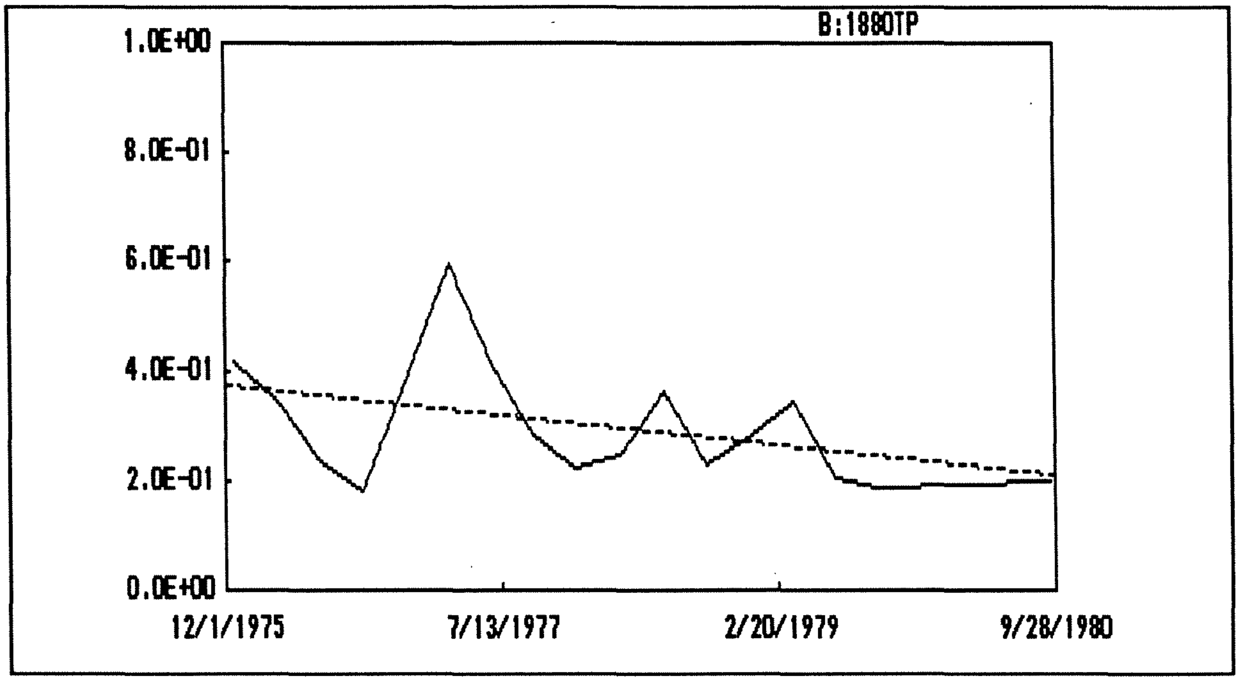


Figure 17. Trend line of quarterly average total phosphorous concentration (as mg/l P) at USGS 07188000 on the Spring River. Slope estimate = -0.03367 mg/l/yr.

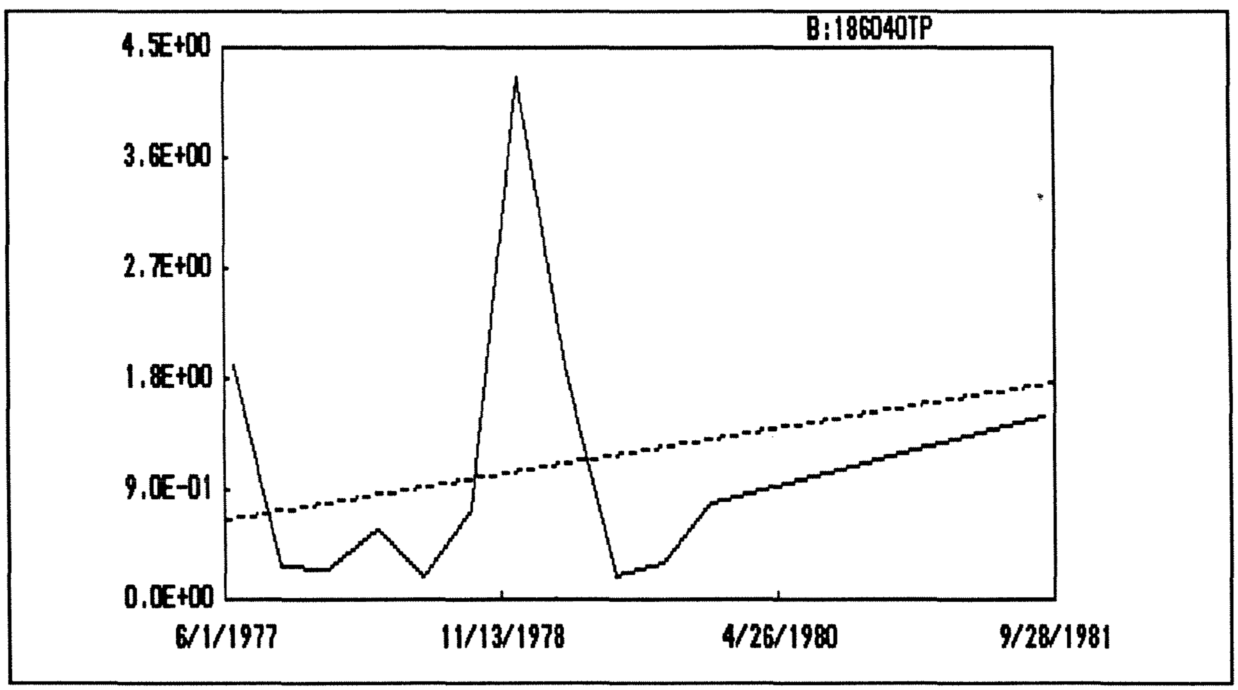


Figure 18. Trend line of quarterly average total phosphorous concentration (as mg/l P) at USGS 07186040 on Cow Creek. Slope estimate = 0.25778 mg/l/yr.

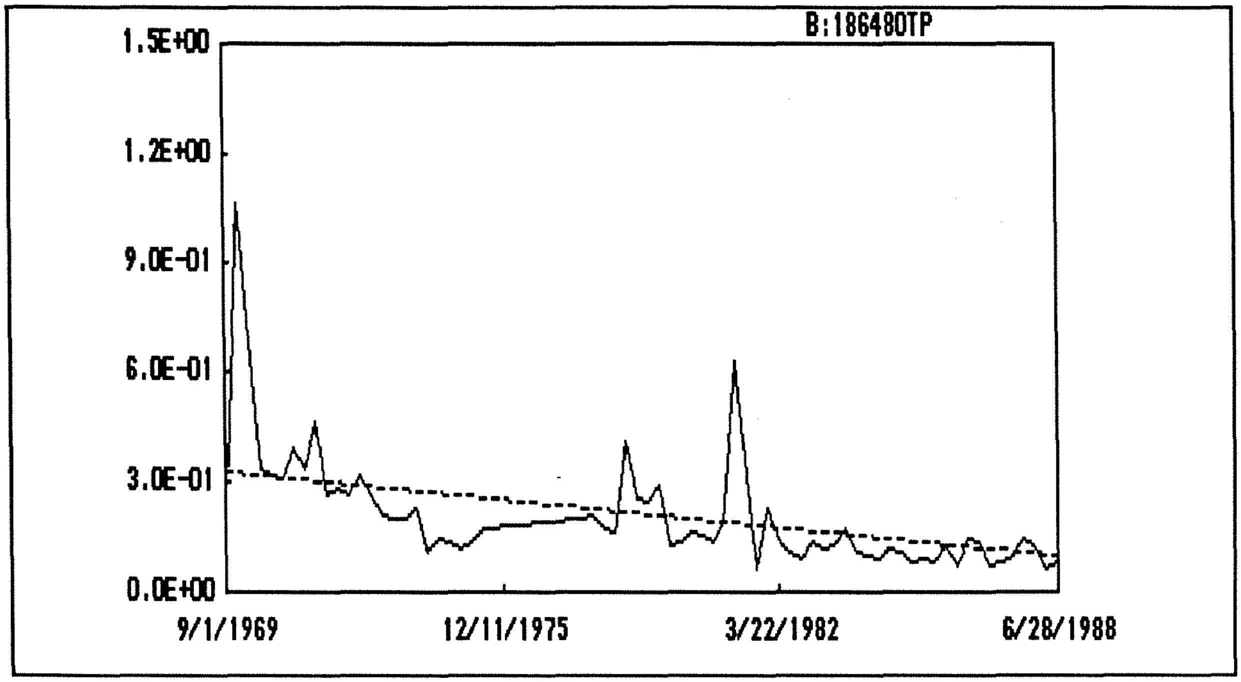


Figure 19. Trend line of quarterly average total phosphorous concentration (mg/l P) at USGS 07186480 on Center Creek. Slope estimate = -0.01240 mg/l/yr.

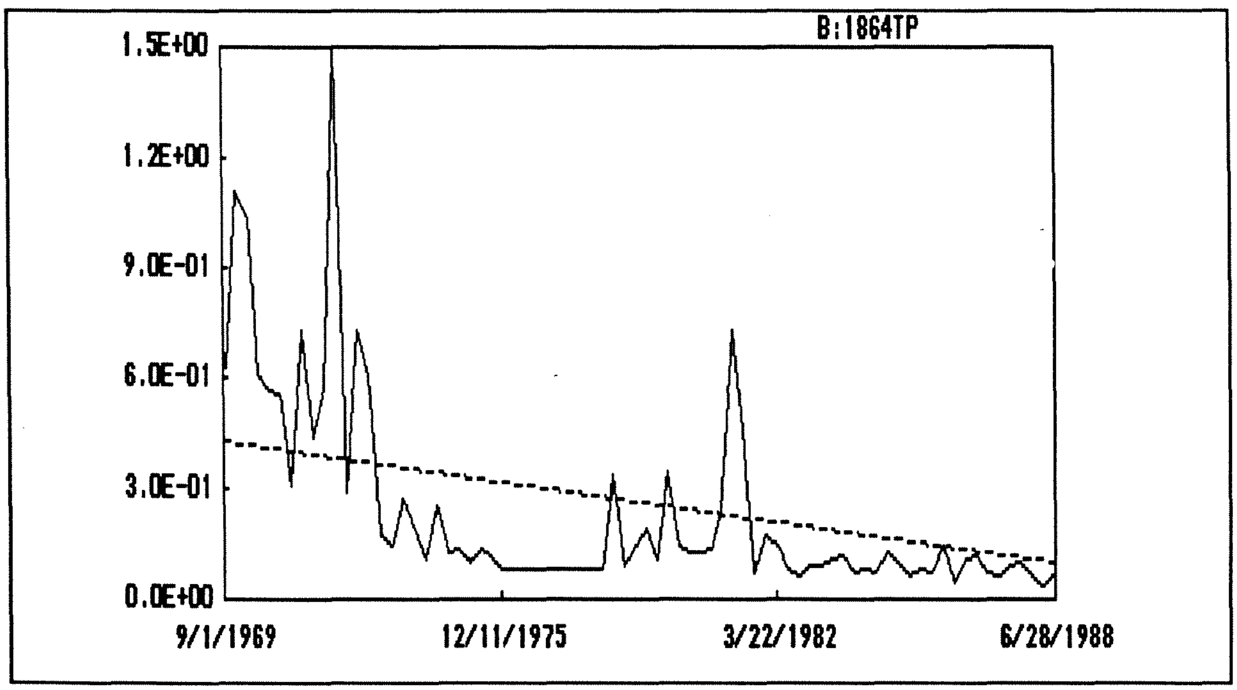


Figure 20. Trend line of quarterly average total phosphorous concentration (mg/l P) at USGS 07186400 on Center Creek. Slope estimate = -0.01730 mg/l/yr.

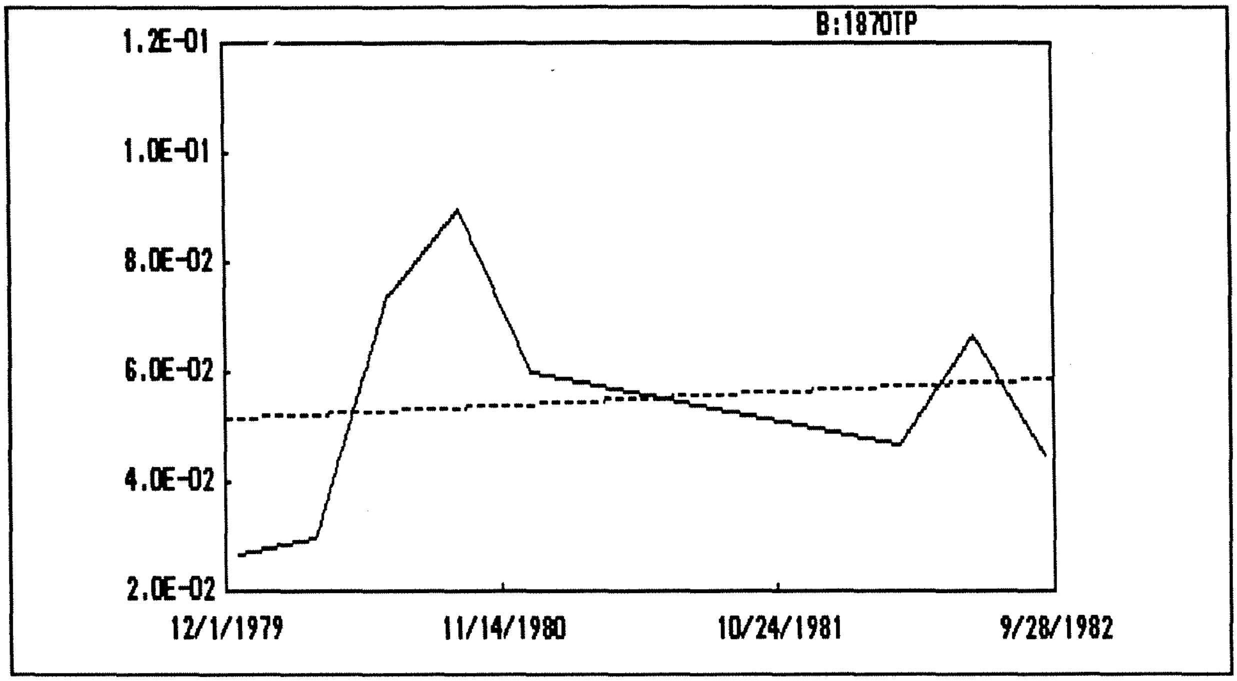


Figure 21. Trend line of quarterly average total phosphorous concentration (mg/l P) at USGS 07187000 on Shoal Creek. Slope estimate = 0.00250 mg/l/yr.

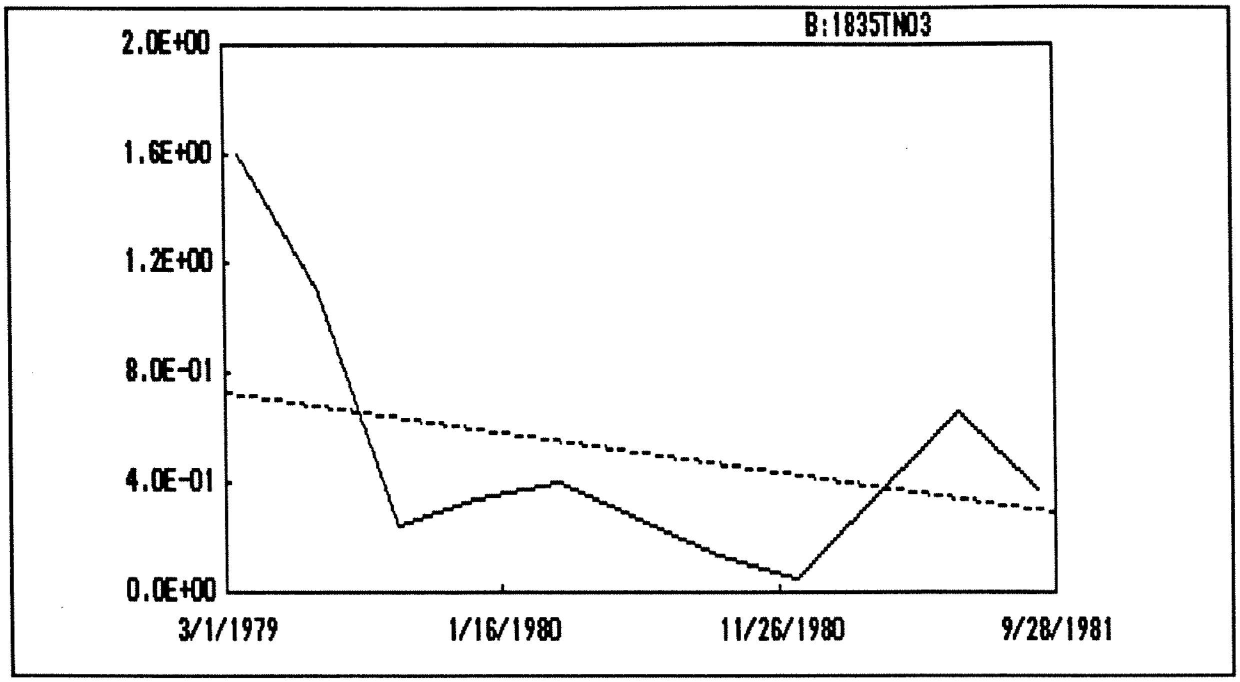


Figure 22. Trend line of quarterly average $NO_2 + NO_3$ concentration (as mg/l N) at USGS 07183500 on the Neosho River. Slope estimate = -0.16833 mg/l/yr.

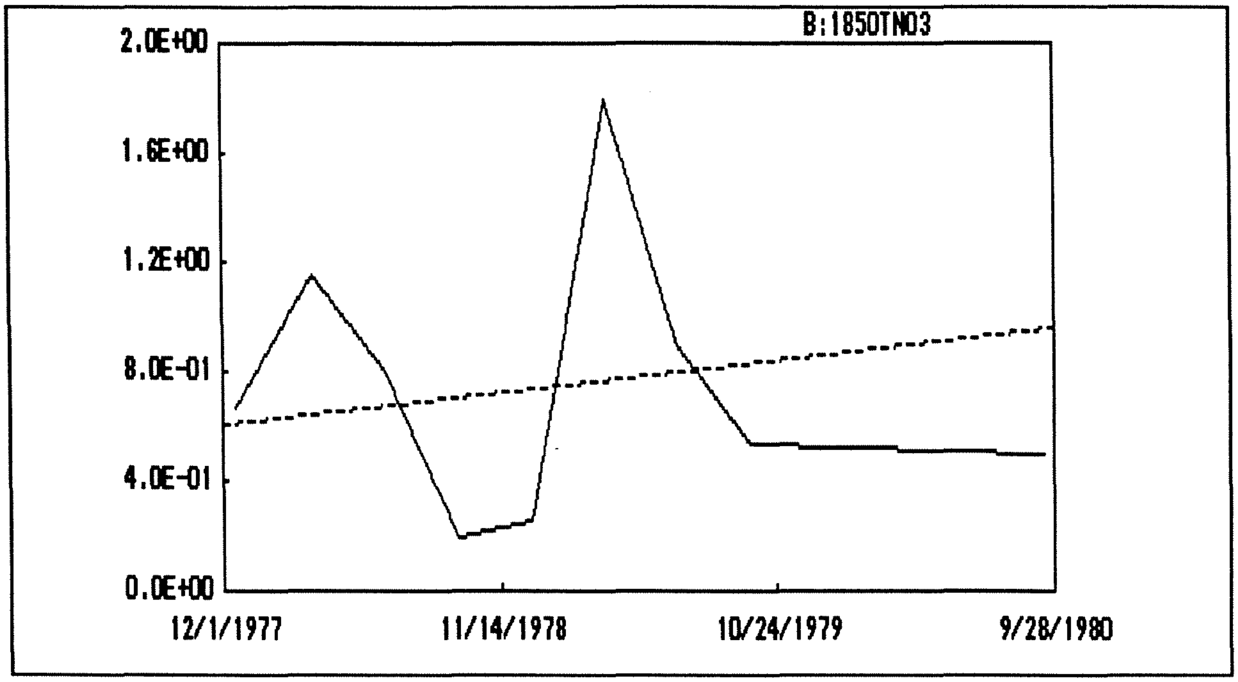


Figure 23. Trend line of quarterly average NO_2 + NO_3 concentration (as mg/l N) at USGS 07185000 on the Neosho River. Slope estimate = 0.12500 mg/l/yr.

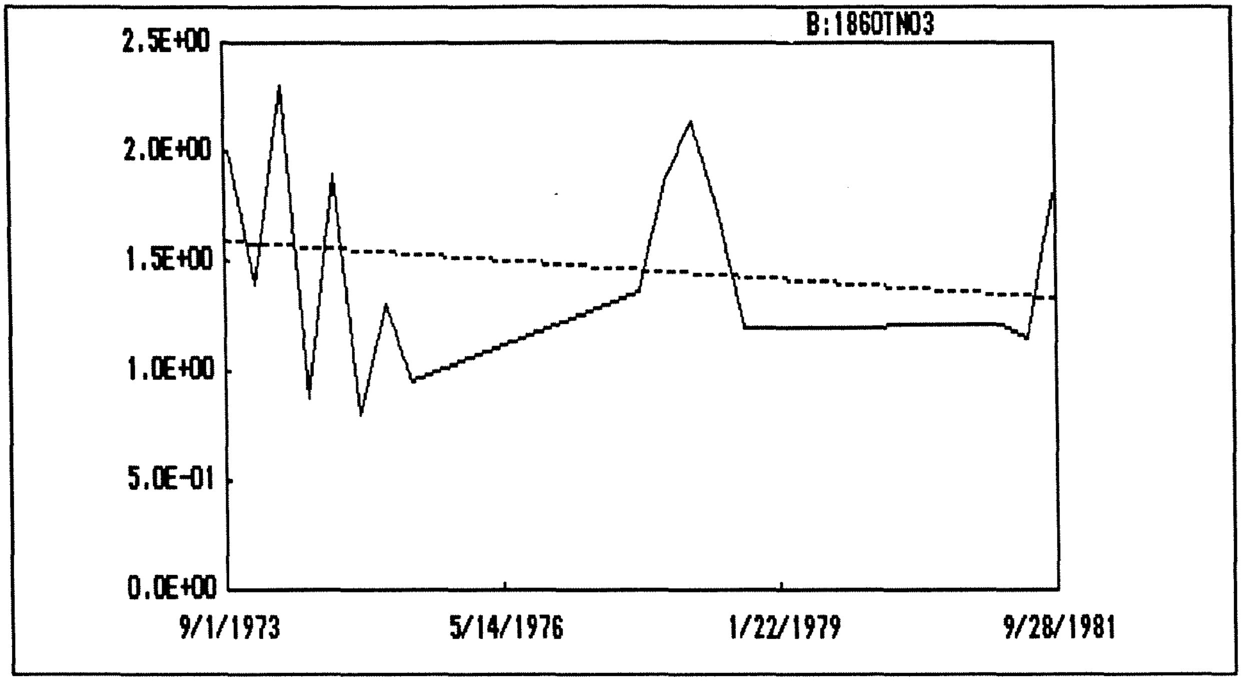


Figure 24. Trend line of quarterly average NO_2 + NO_3 concentration (as mg/l N) at USGS 07186000 on the Spring River. Slope estimate = -0.03200 mg/l/yr.

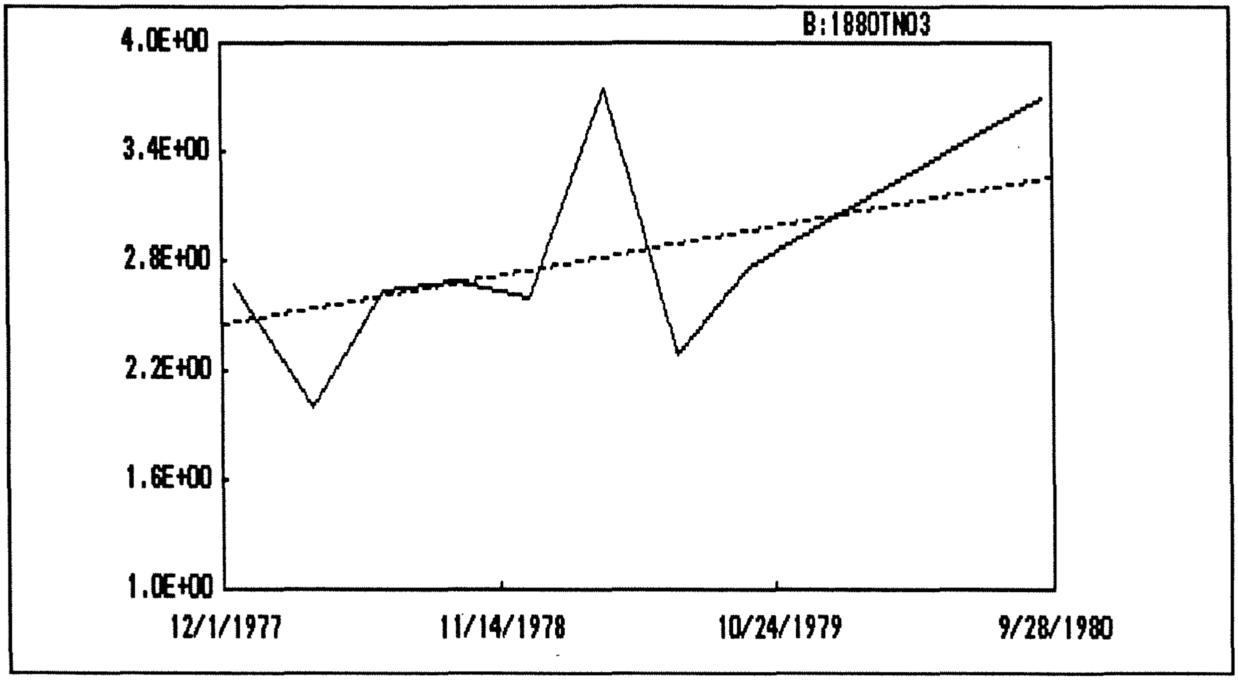


Figure 25. Trend line of quarterly average NO_2 + NO_3 concentration (as mg/l N) at USGS 07188000 on the Spring River. Slope estimate = 0.28333 mg/l/yr.

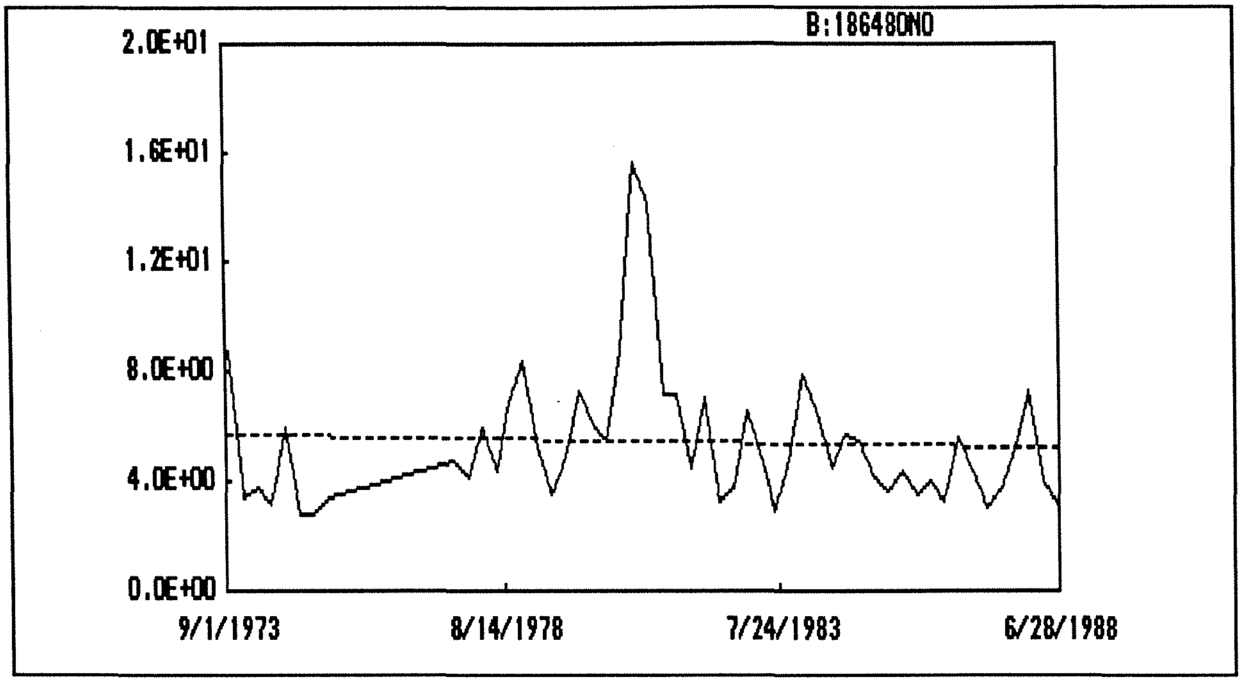


Figure 26. Trend line of quarterly average NO_2 + NO_3 concentration (as mg/l N) at USGS 07186480 on Center Creek. Slope estimate = -0.03472 mg/l/yr.

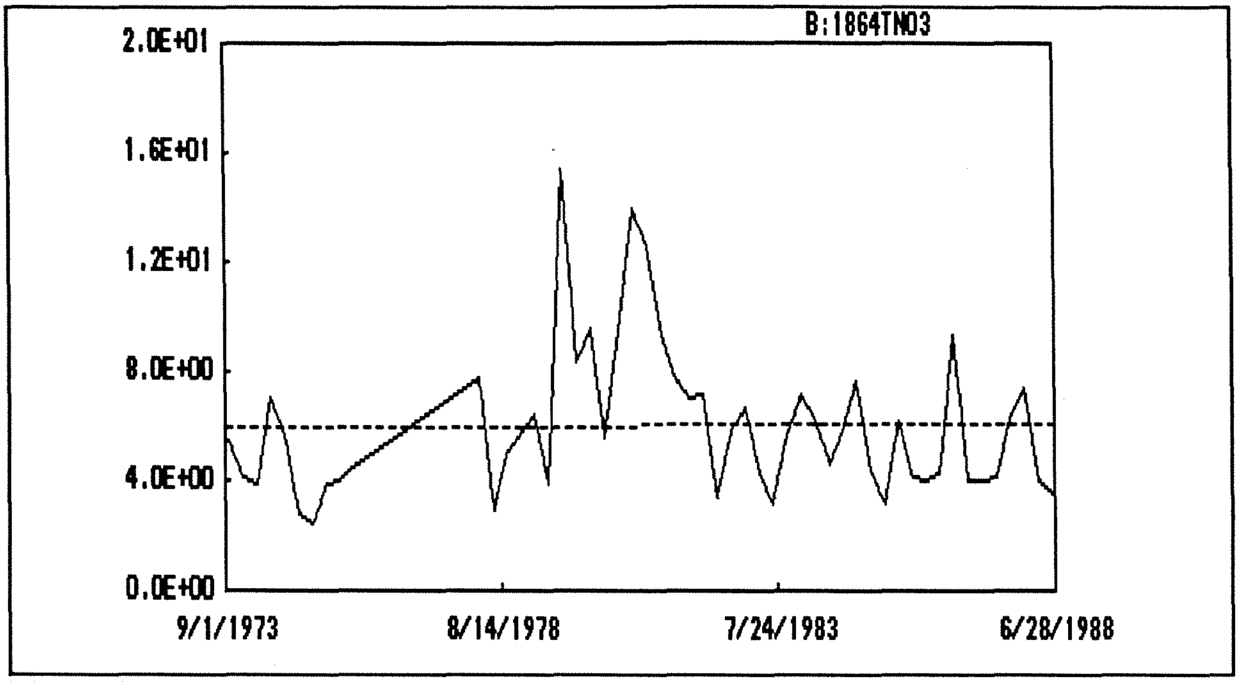


Figure 27. Trend line of quarterly average NO_2 + NO_3 concentration (as mg/l N) at USGS 07186400 on Center Creek. Slope estimate = 0.00519 mg/l/yr.

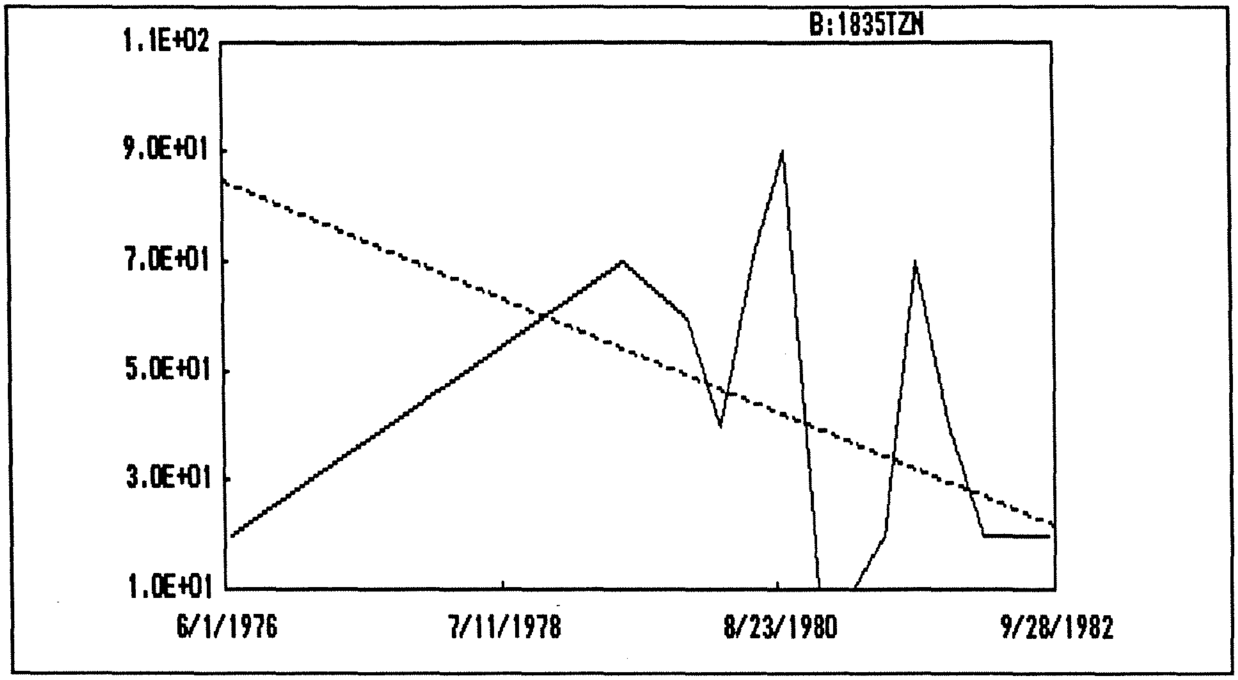


Figure 28. Trend line of quarterly average total zinc concentration (as ug/l Zn) at USGS 07183500 on the Neosho River. Slope estimate = -10.00 ug/l/yr.

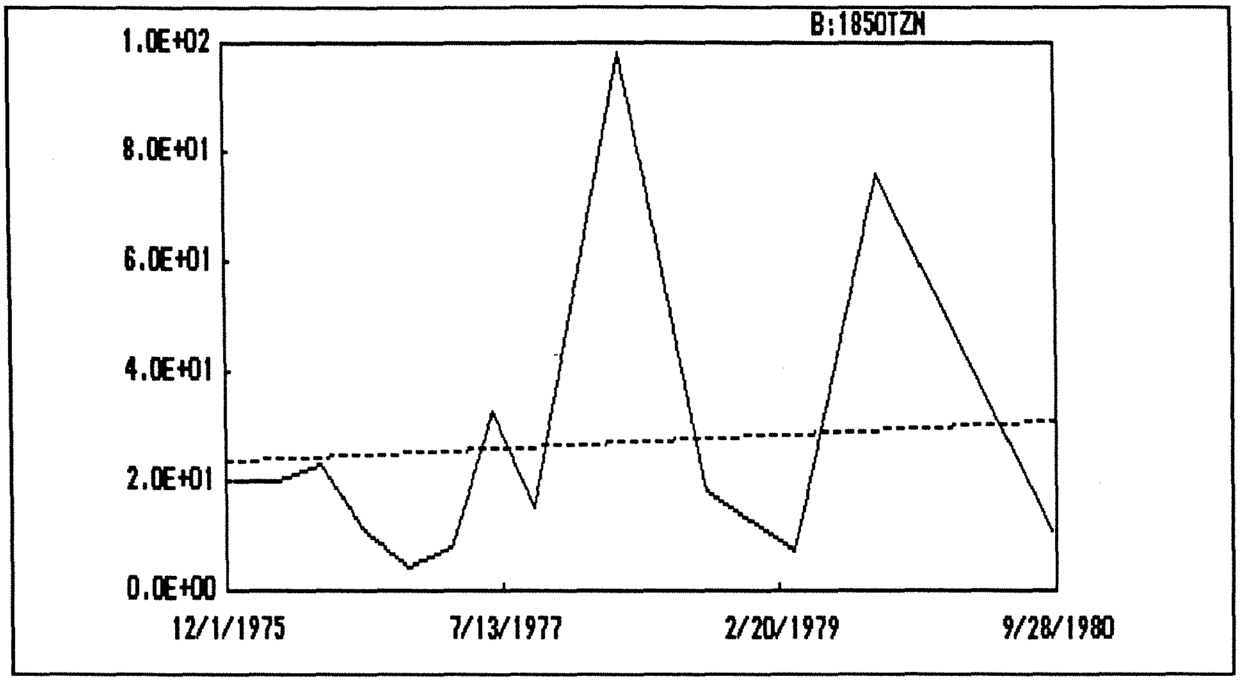


Figure 29. Trend line of quarterly average total zinc concentration (as ug/l Zn) at USGS 07185000 on the Neosho River. Slope estimate = 1.5 ug/l/yr.

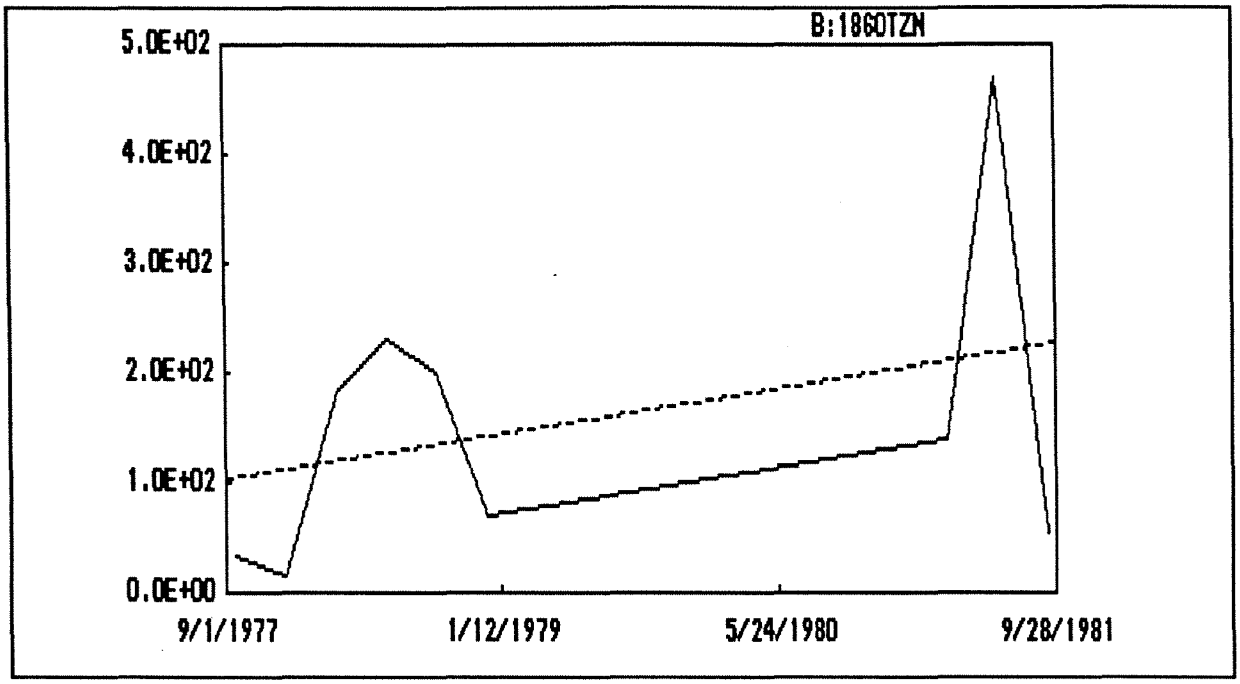


Figure 30. Trend line of quarterly average total zinc concentration (as ug/l Zn) at USGS 07186000 on the Spring River. Slope estimate = 30.375 ug/l/yr.

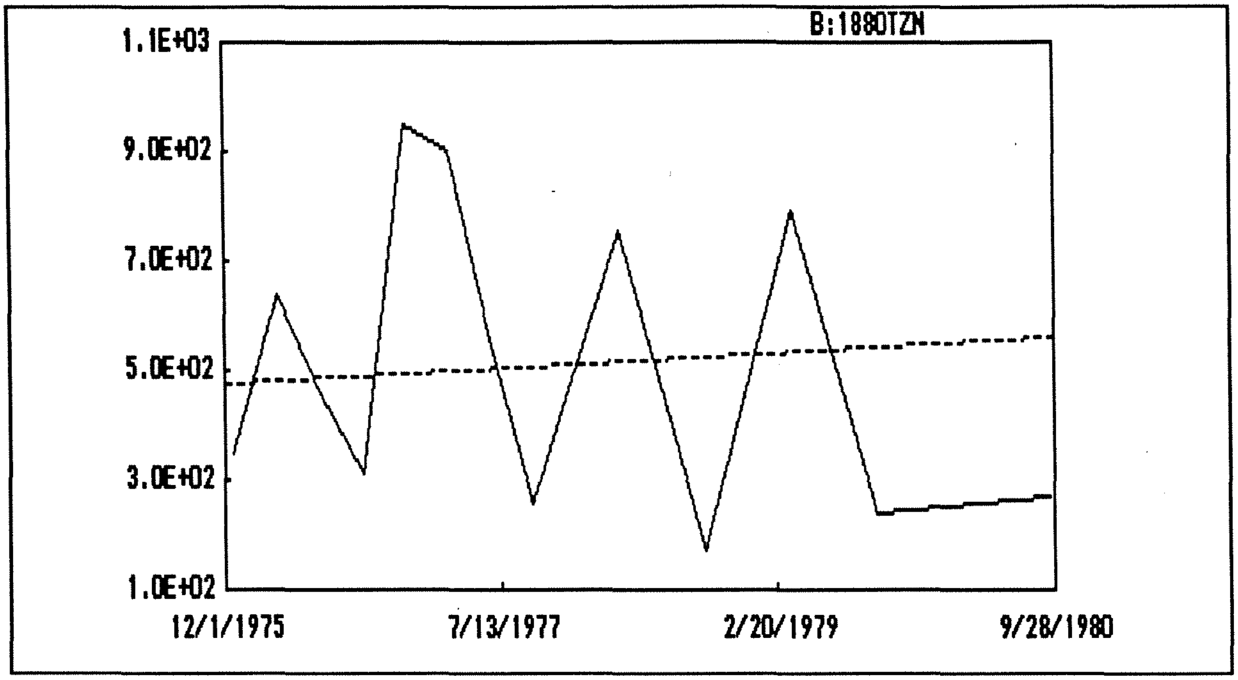


Figure 31. Trend line of quarterly average total zinc concentration (as ug/l Zn) at USGS 07188000 on the Spring River. Slope estimate = 16.83 ug/l/yr.

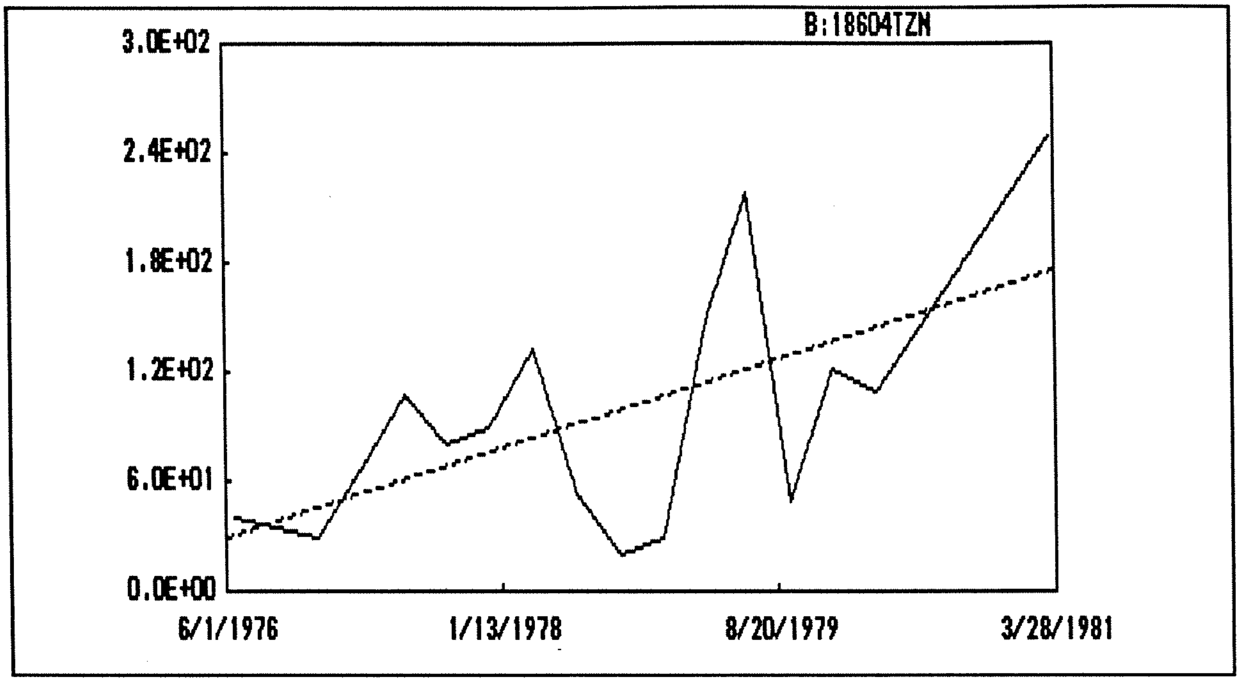


Figure 32. Trend line of quarterly average total zinc concentration (as ug/l Zn) at USGS 07186040 on Cow Creek, Kansas. Slope estimate = 30.476 ug/l/yr.

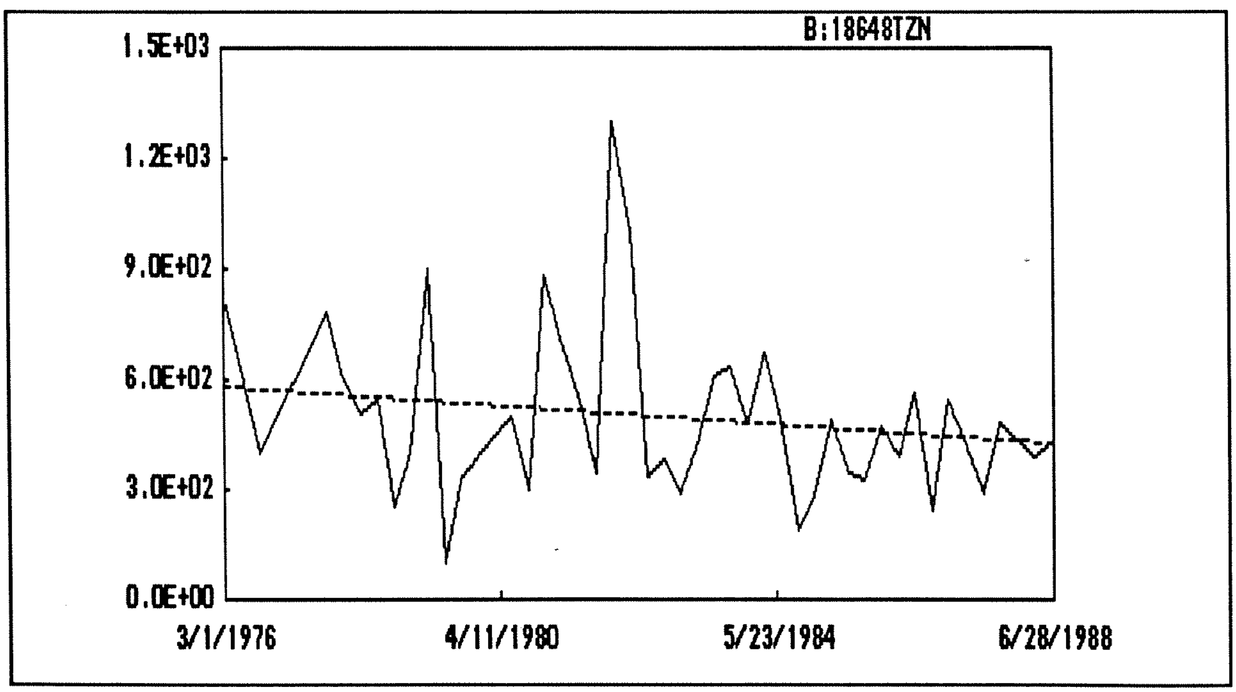


Figure 33. Trend line of quarterly average total zinc concentration (as ug/l Zn) at USGS 07186480 on Center Creek, Missouri. Slope estimate = -12.33 ug/l/yr.

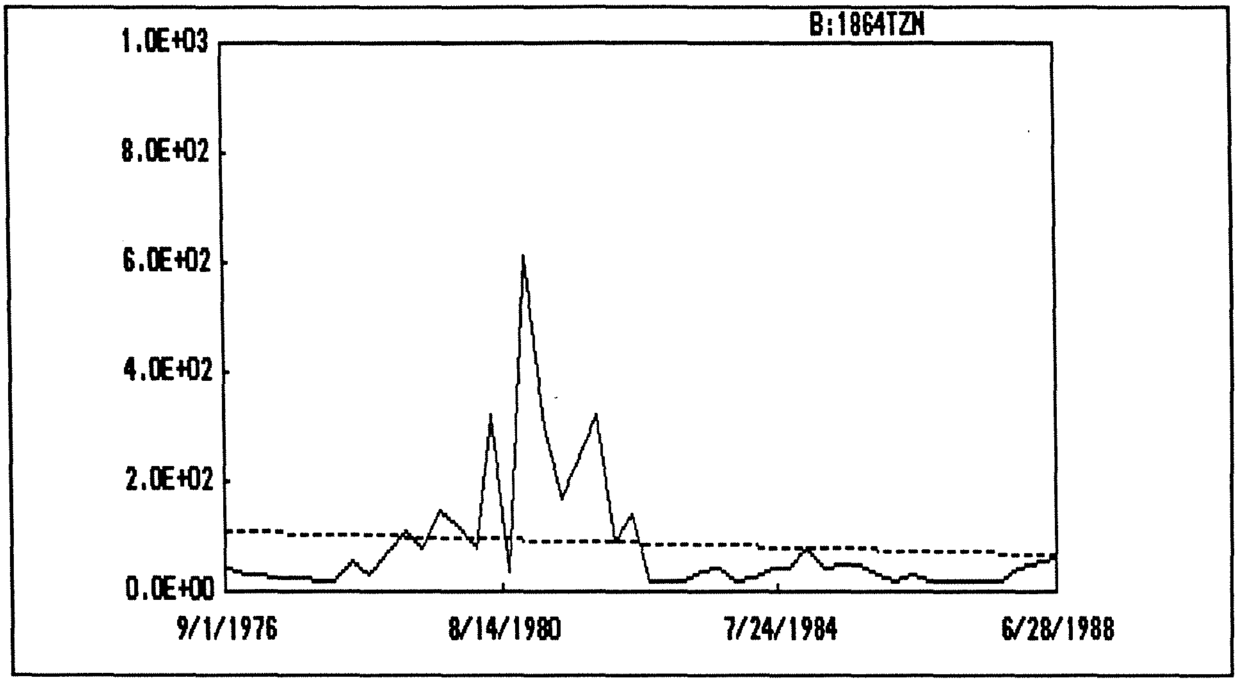


Figure 34. Trend line of quarterly average total zinc concentration (as ug/l Zn) at USGS 07186400 on Center Creek, Missouri. Slope estimate = -4.00 ug/l/yr.

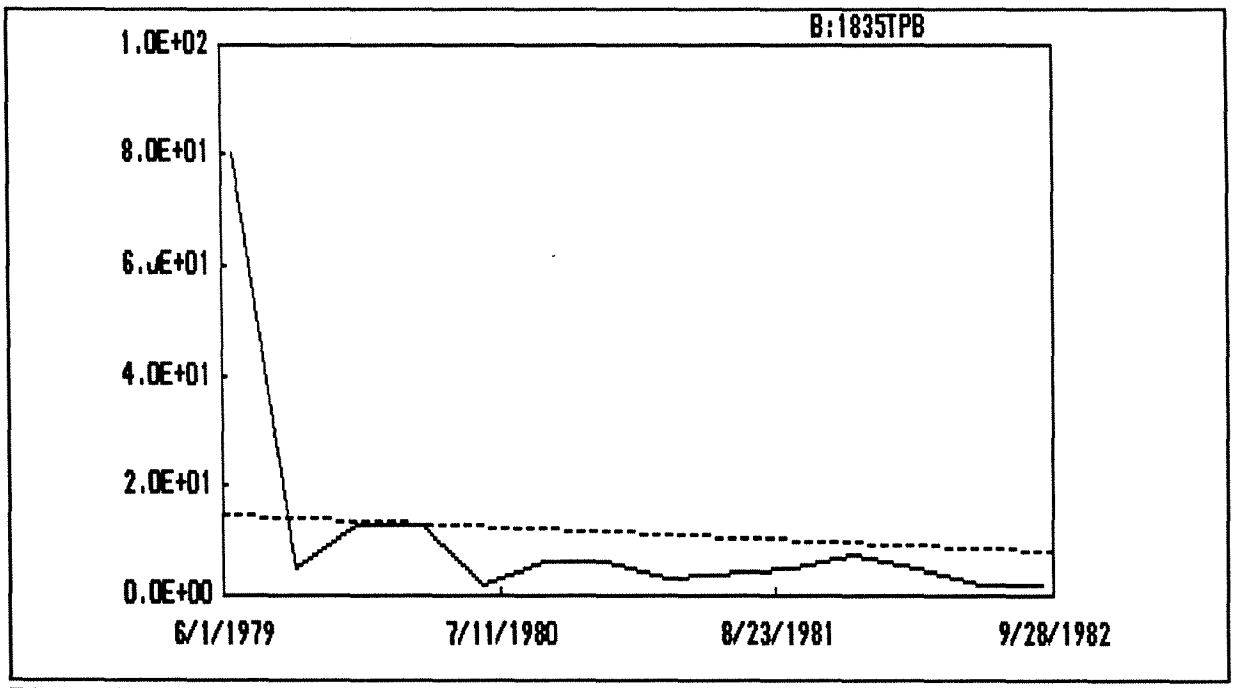


Figure 35. Trend line of quarterly average total lead concentration (as ug/l Pb) at USGS 07183500 on the Neosho River. Slope estimate = -2.00 ug/l/yr.

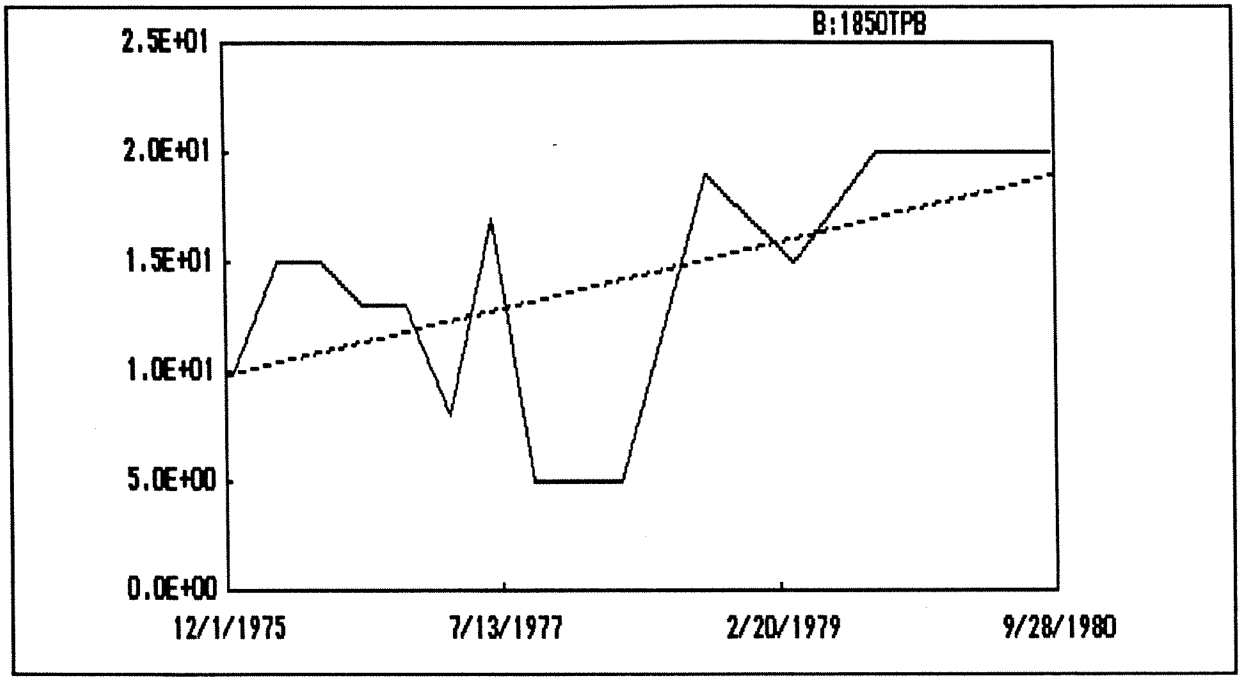


Figure 36. Trend line of quarterly average total lead concentration (as ug/l Pb) at USGS 07185000 on the Neosho River. Slope estimate = 1.875 ug/l/yr.

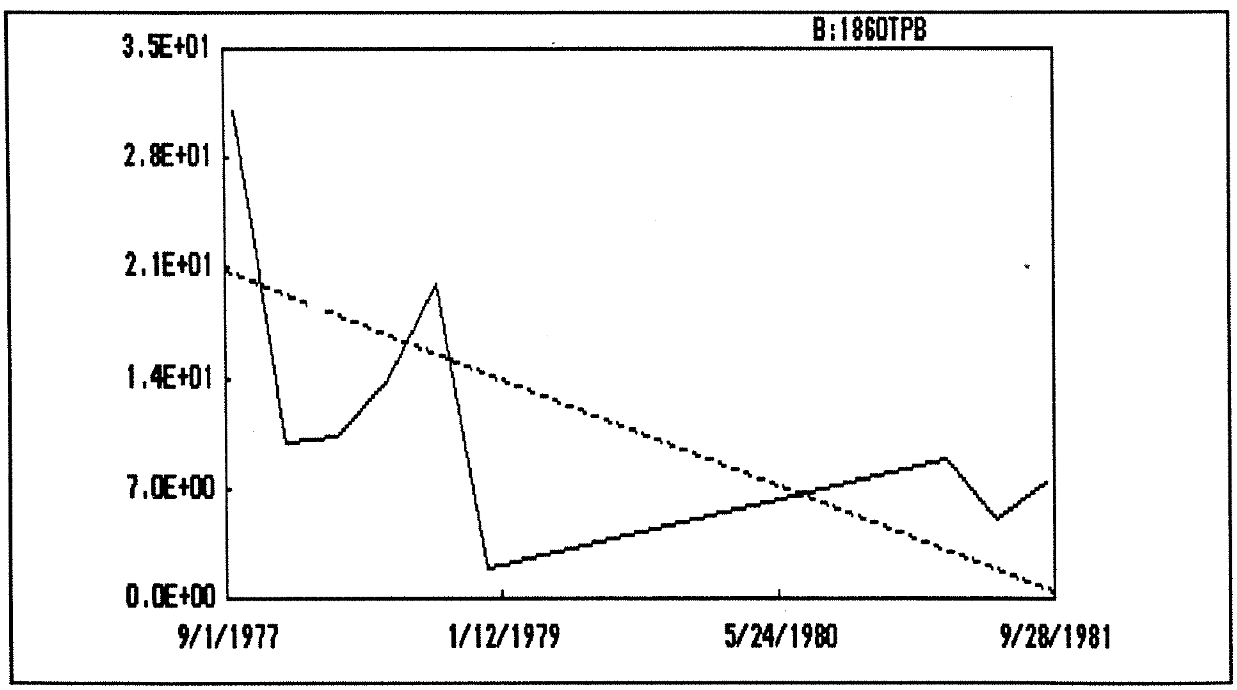


Figure 37. Trend line of quarterly average total lead concentration (as ug/l Pb) at USGS 07186000 on the Spring River. Slope estimate = -5.00417 ug/l/yr.

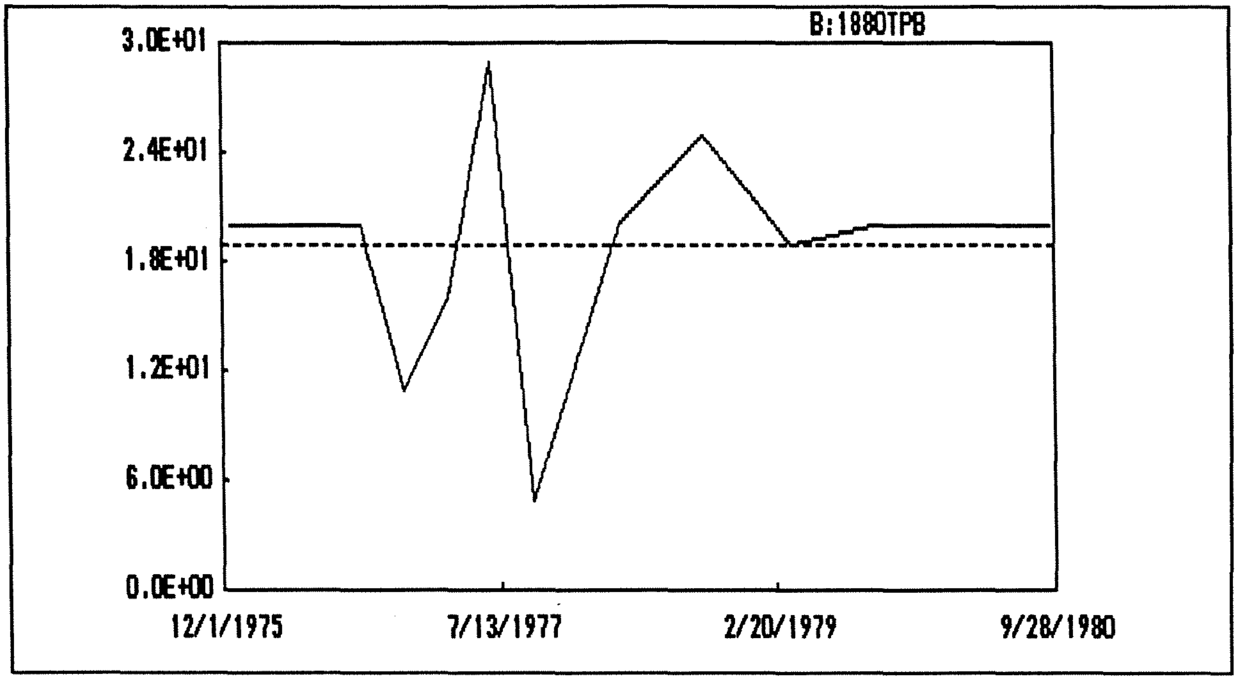


Figure 38. Trend line of quarterly average total lead concentration (as ug/l Pb) at USGS 07188000 on the Spring River. Slope estimate = 0.00 ug/l/yr.

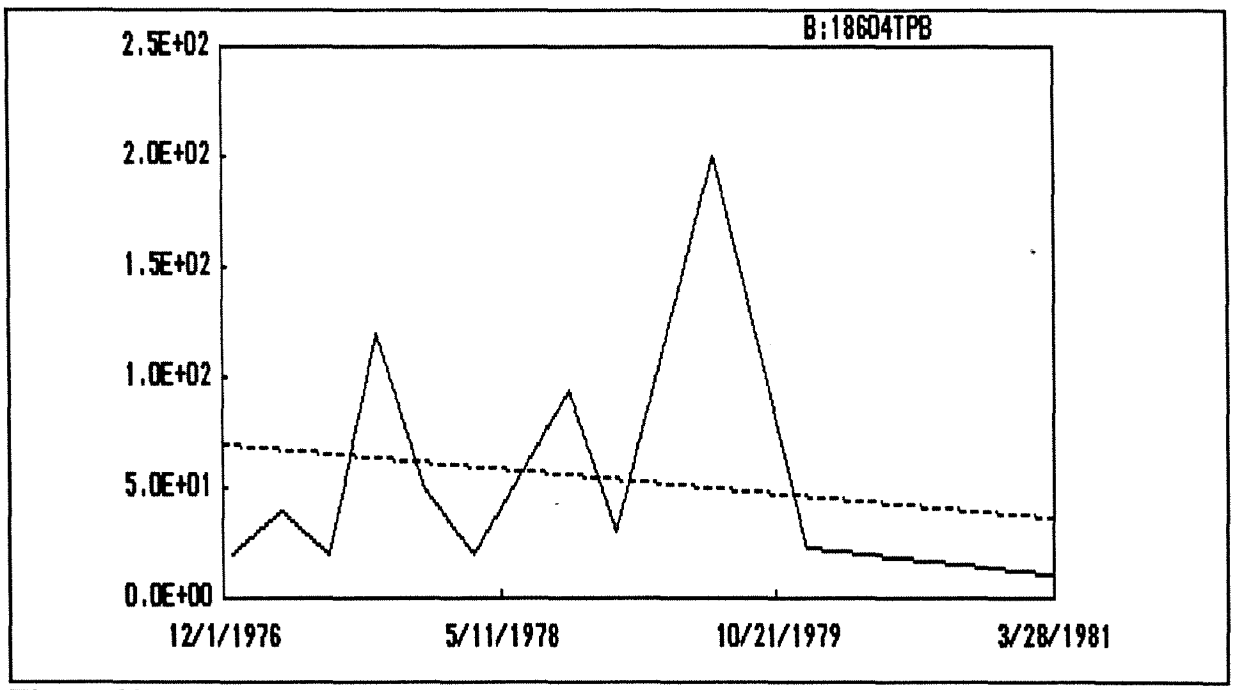


Figure 39. Trend line of quarterly average total lead concentration (as ug/l Pb) at USGS 07186040 on Cow Creek, Kansas. Slope estimate = -7.50 ug/l/yr.

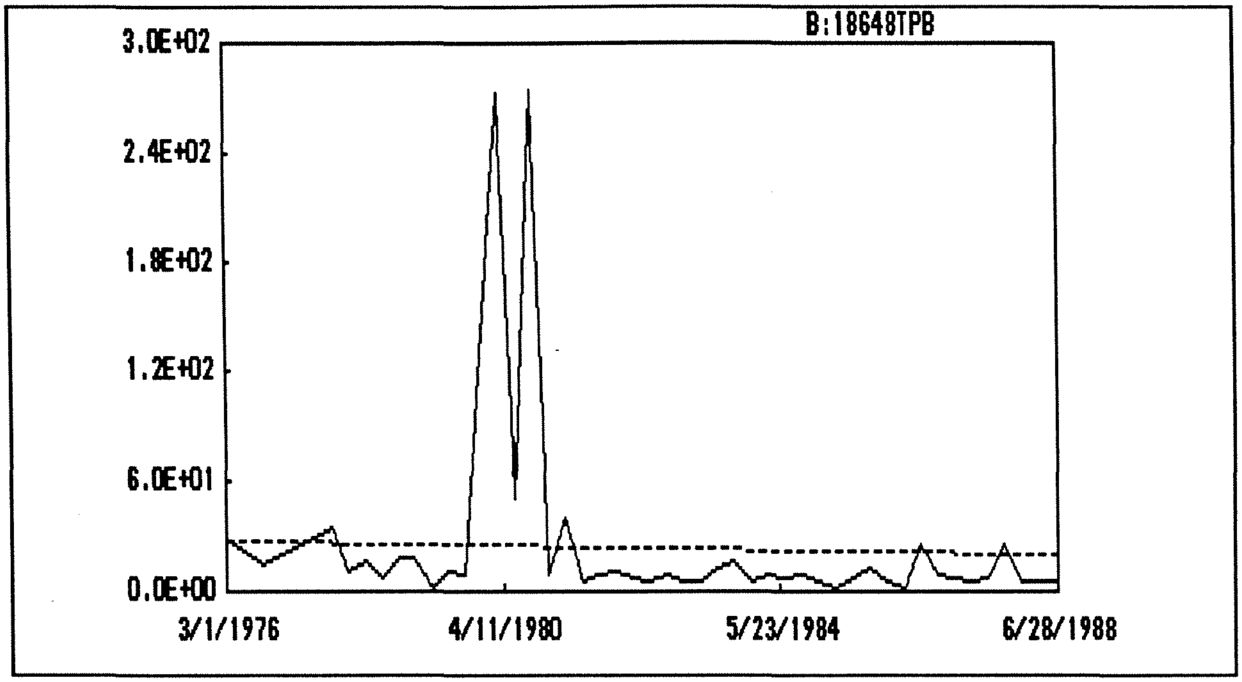


Figure 40. Trend line of quarterly average total lead concentration (as ug/l Pb) at USGS 07186480 on Center Creek, Missouri. Slope estimate = 0.64583 ug/l/yr.

SUBOUTPUT 11b: Morphometry

METHOD: The following parameters will be determined from existing data on Grand Lake: length (l), width (w), shore line length (L), shoreline development (D_L), and drainage area. Maximum depth will be determined with a sonar depth finder. GRDA has planned a detailed morphometric study as part of their FERC permit application and therefore will not be included as part of the tasks under the "Clean Lakes Project".

Grand Lake has a max depth of 164 ft, and mean depth = 35.9 feet (Oklahoma Water Atlas, 1984). The power pool elevation of Grand Lake is 745 feet above sea level. The surface area at power pool elevation is 46,500 acres and capacity is 1,672,000 acre feet. The average discharge for the period from 1939-89 was 7,208 cfs.

The EPA study in 1974 found the following characteristics for Grand Lake:

1. mean hydraulic retention time of 129 days based upon dividing lake volumne by mean flow of outlet.

2. mean flow of outlet 183.86 m3/sec

Table 40. Summary of morphological characteristics of Grand Lake.

Morphological Feature	Normal Pool	Flood Pool
Elevation (Ft above MSL) (NGVD)	745	755
Area (Acres)	46,500	59,200
Capacity (Acre-feet)	1,672,000	2,197,000
Mean Depth, feet at normal pool elevation	35.9	
Maximum Depth, feet at normal pool elevation	164	
Shoreline, miles	624	
Shoreline development	20.1	
Volume developmnent	0.66	

OWRB, Oklahoma Water Atlas 1984

SUBTASK 11c: Hydraulic Budget

METHOD: Data Analyses:

Lake levels and precipitation records from GRDA and U. S. Weather Bureau

Discharge and hydroelectric generation records from GRDA.

Total usage of municipal water fromlocal city records.

Use general records to estimate pan evaporation

Table 41. Summary of hydraulic characteristics of Grand Lake.

Source	Drainage Area (sq. mi.)	Discharge cfs	Percent of Total*
Neosho River	5,876	3652	51
Spring River	2,510	2050	28
Elk River	872	803	11
Sum of Above	9,258	6505	90
Below Dam	10,298	7208	100

* calculated as percent of discharge below dam, USGS 1989

SUBTASK 11d: Physicochemical Conditions of the Water

Current Physicochemical Conditions in Grand Lake

Hardness and Alkalinity

Grand Lake is classified as a moderately hard water lake (Wetzel 1983). The water is of the $CaCO_3$-type. The alkalinity and hardness in the headwaters (e.g. Station 1) showed greater variation than in the quiescent waters near the dam (e.g. Station 4) (Figure 41 and Figure 42). This arrangement can be expected due to the magnified effects of seasonal runoff regimes in the basin causing changes in the headwaters but are buffered in the lower reaches from precipitation/ settling in the transition zone (i.e., Station 1 --> Station 2) and subsequent dilution in the lacustrine zone (i.e., Station 3 & 4). Additionally, the higher $CaCO_3$ in the headwaters is probably acting as a partially protective mechanism of downstream phosphate enrichment by minimizing the solubility of phosphate through calcite coprecipitation.

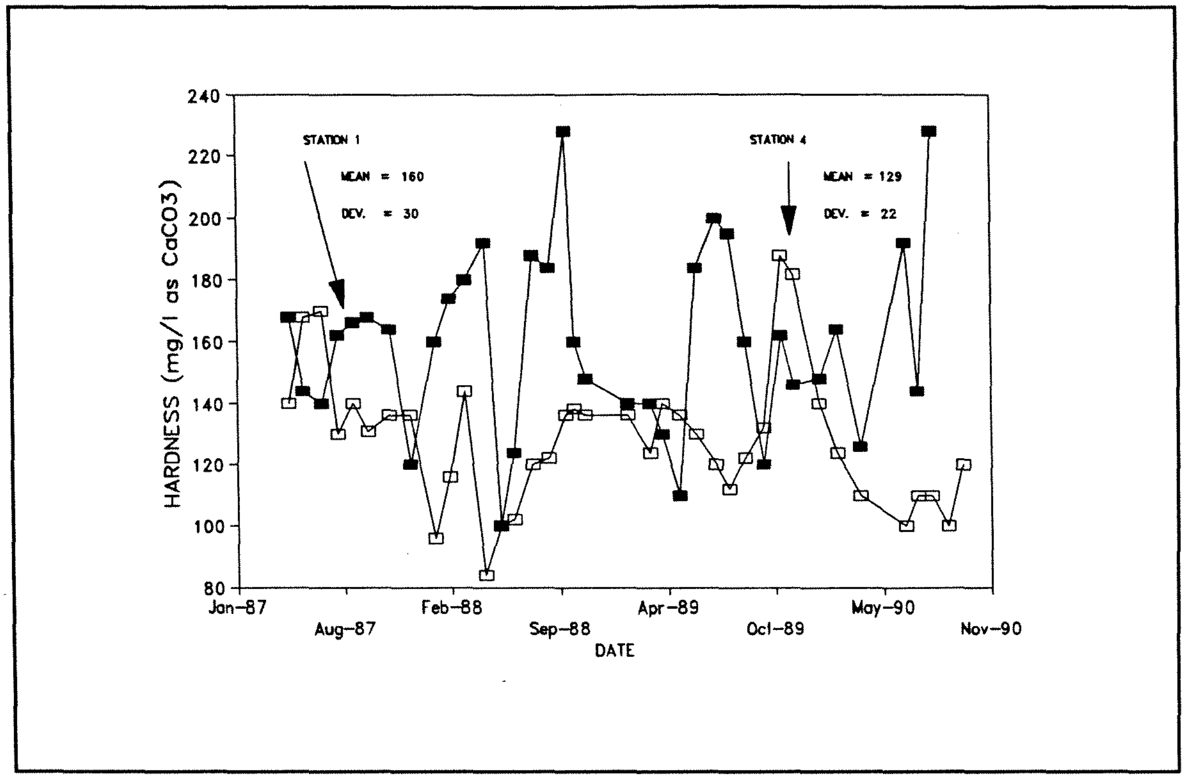


Figure 41. Hardness for Grand Lake Stations 1 & 4.

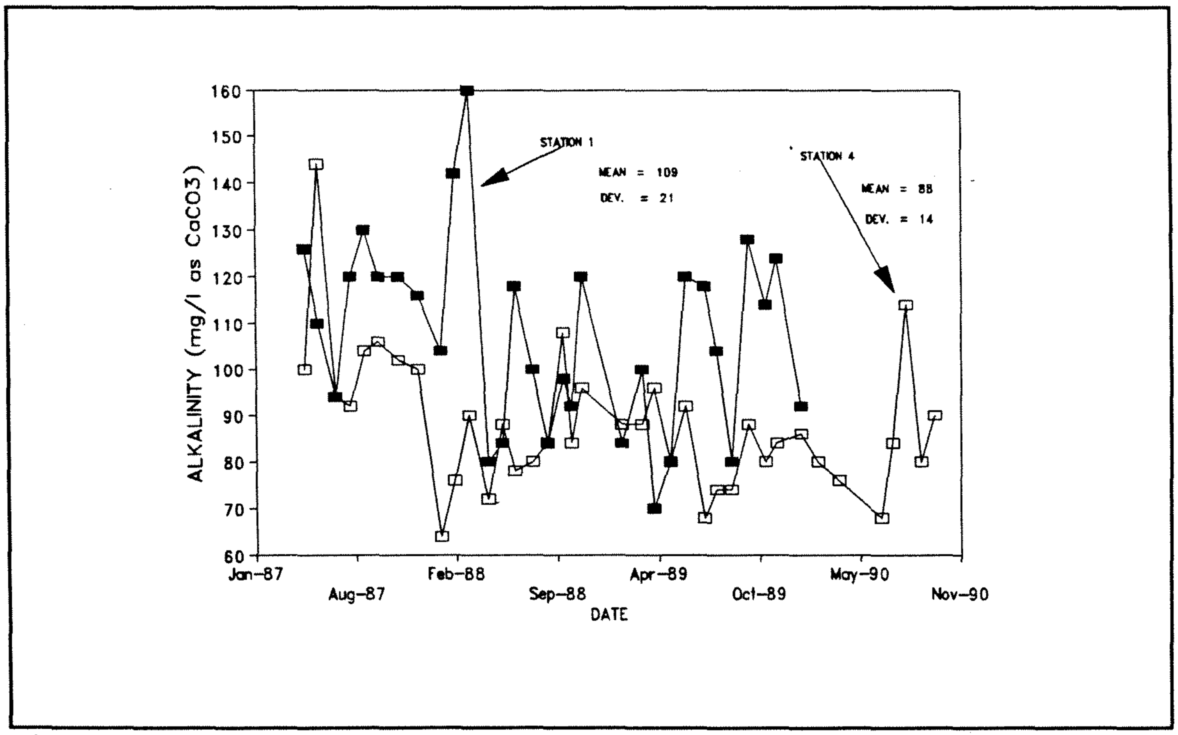


Figure 42. Alkalinity for Grand Lake Stations 1 & 4.

Grand Lake is generally alkaline and shows distinct pH shifts during summer stratification. The decrease in hypolimnetic pH exacerbates phosphate resolubilization and thus accelerates eutrophication. Studies have shown that that anoxic hypolimnia are associated with these pH shifts. It is noted, however, that the pH shift towards the acid side is a result (thus an indication) of accelerated eutrophication and thus should not be considered a causal factor in making decisions on corrective measures. However, it can and should be used as an indicator of effectiveness of restorative measures. Although only stations 1-4 are illustrated (Figure 44-Figure 46), the other stations indicate similar patterns, with less drastic hypolimnetic pH shifts for those stations further from the dam.

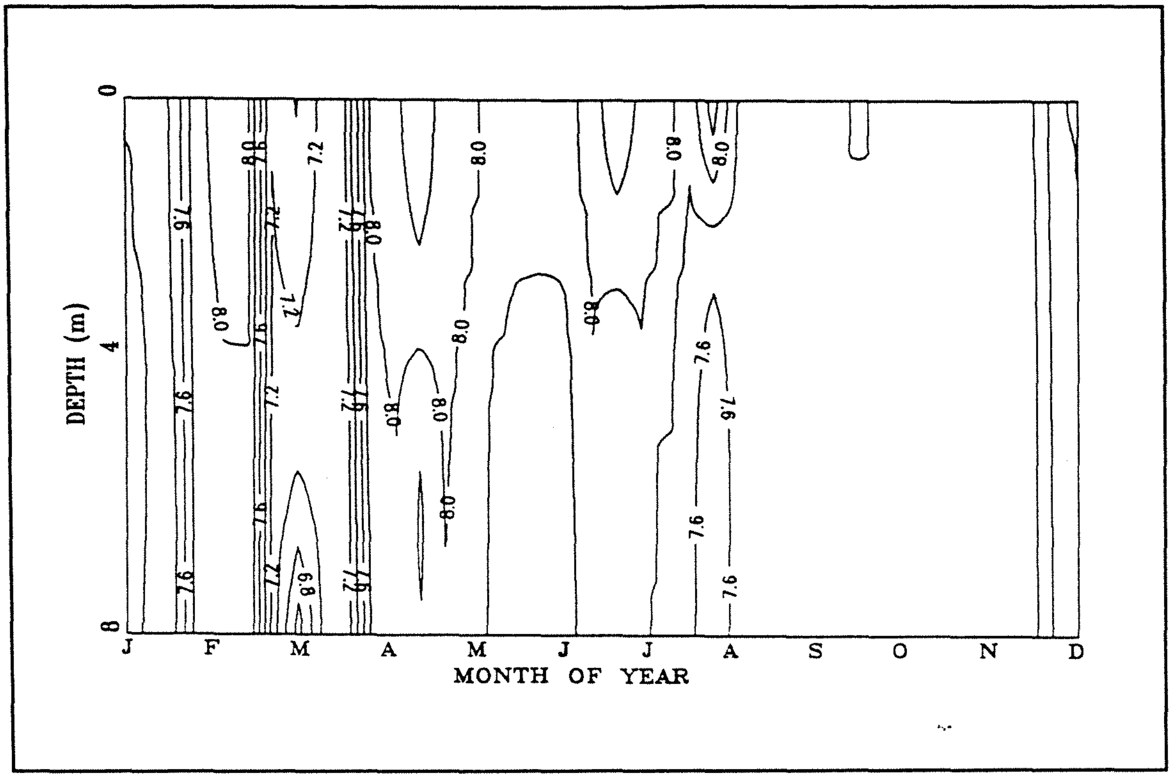


Figure 43. Grand Lake station 1 pH isopleth, CY89.

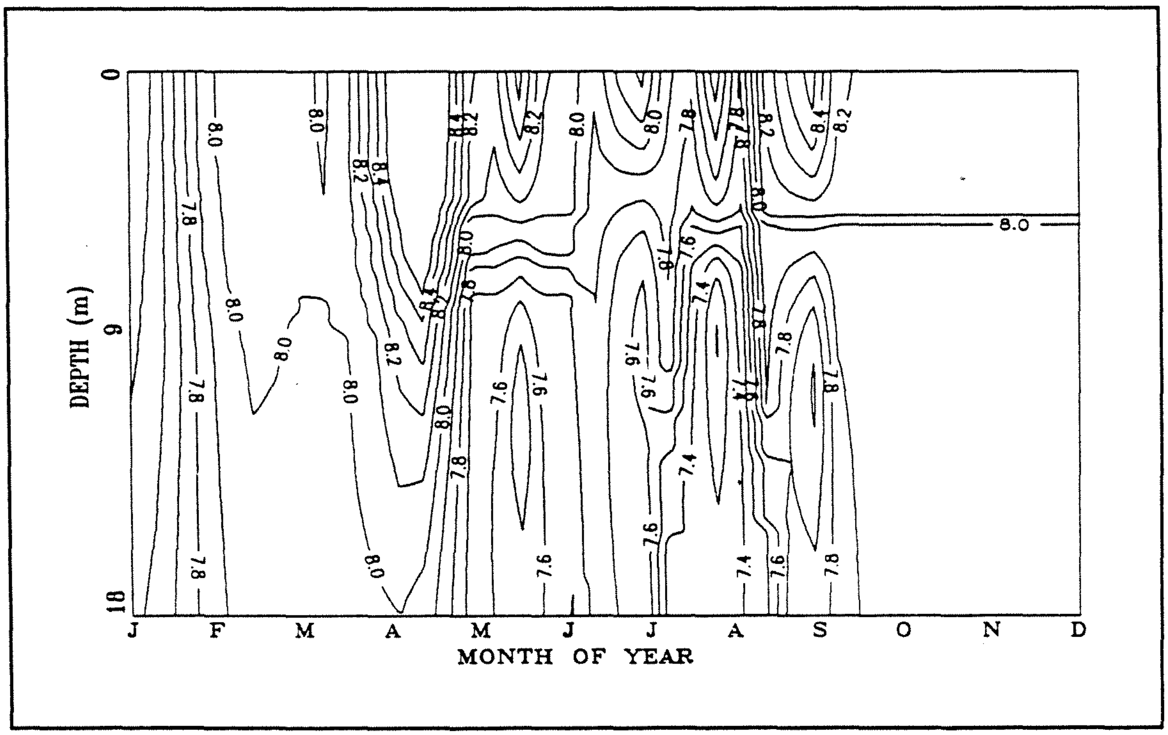


Figure 44. Grand Lake station 2 pH isopleths, CY89.

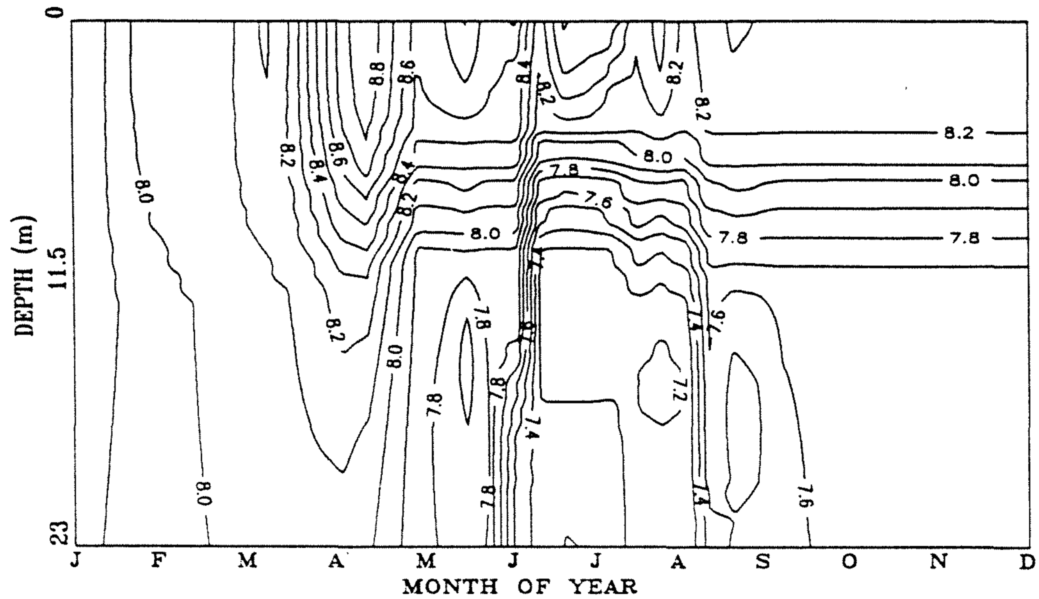


Figure 45. Grand Lake station 3 pH isopleths, CY89.

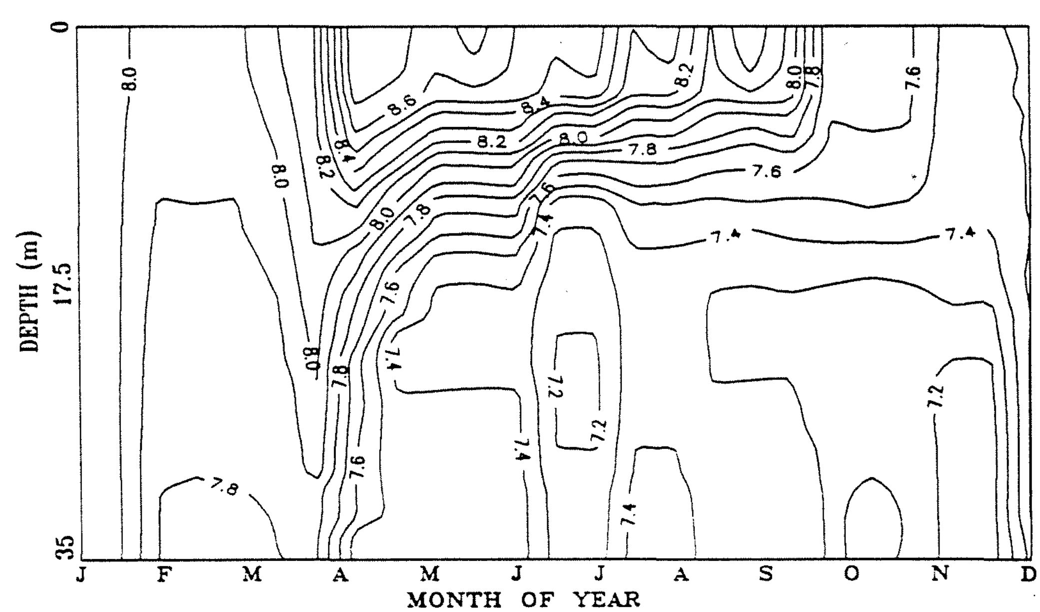


Figure 46. Grand Lake station 4 pH isopleth, CY89.

The shift in hypolimnetic pH towards more acidity also represents an increased threat to sediment release of toxic metals that are currently trapped in the headwater sediments. For this reason and its use as an indicator of eutrophication potential, we feel that any monitoring program should include frequent hypolimnetic pH measurements, especially during summer stratification. Restorative measures should be directed towards reducing these shifts.

Temperature and Dissolved Oxygen

The mean annual temperature (atmospheric) at Grand Lake is 58° C (OWRB 1990). The surface temperatures ranged from 4 to 28 °C. The lake remained relatively mixed during the winter months for the years '87-'90. Station 1 did not thermally stratify (Figure 47). Station 2 exhibited thermal stratification between June and late September (Figure 48). Station 3 stratified ca. May and began to mix in late September (Figure 49). Station 4 exhibited strong thermal stratification beginning in May and mixing ca. late October-November (Figure 50). We feel that the stronger stratification observed at the lower end reflects the deeper depth coupled with a greater area (and thus volume). Because thermal regimes are dictated by climatic conditions, we assume the available data represents typical conditions, and thus we classify it as a warm monomictic lake (Wetzel 1983).

Dissolved oxygen dynamics in Grand Lake exemplify those in a eutrophic reservoir. Shortly after thermal stratification begins, the oxygen content of the hypolimnion decreases (Figure 51 - Figure 54). This condition is worse at the sediment water interface (presumably from its relatively higher BOD). Hypolimnetic anoxia at station 4 occurred approximately 1-3 weeks after the onset of thermal stratification and did not change until autumnal mixing (Figure 54 - Figure 55). Station 3 showed a longer lag before anoxia (Figure 53). Station 2 showed anoxia for about 2 months before autumnal mixing (Figure 52). Although anoxia was not observed for a significant time at station 1, a definite oxygen deficit was

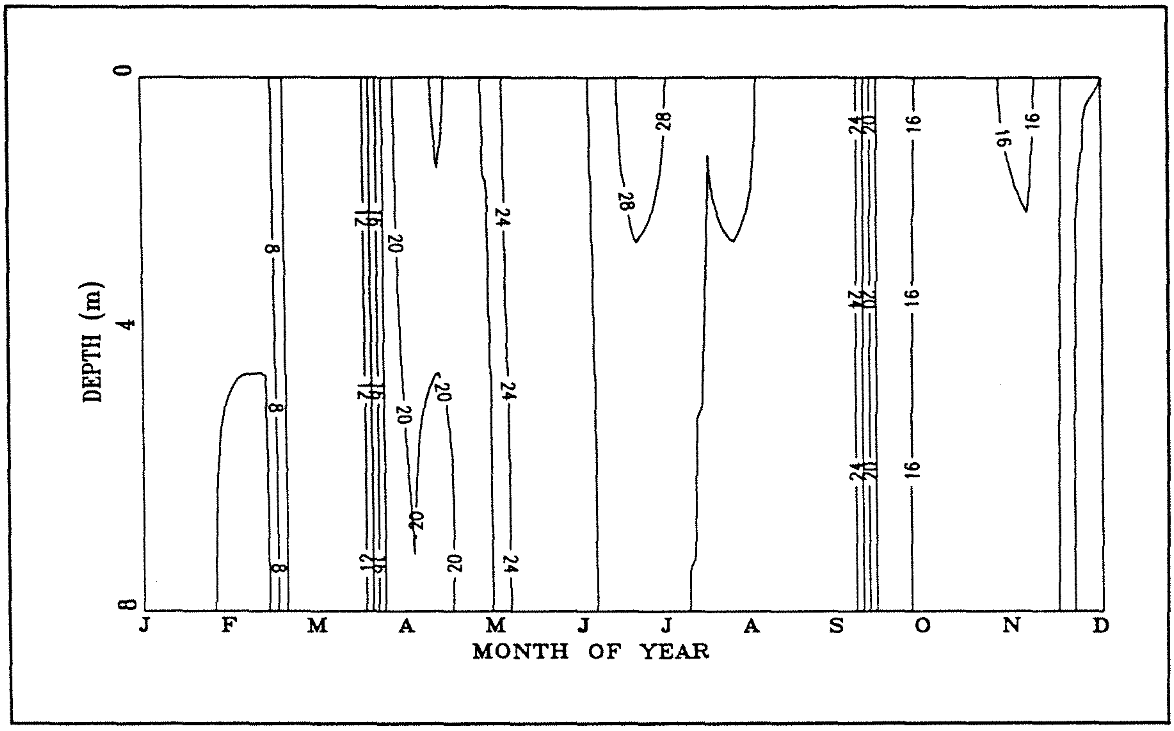


Figure 47. Grand Lake station 1 thermal isopleth, CY89.

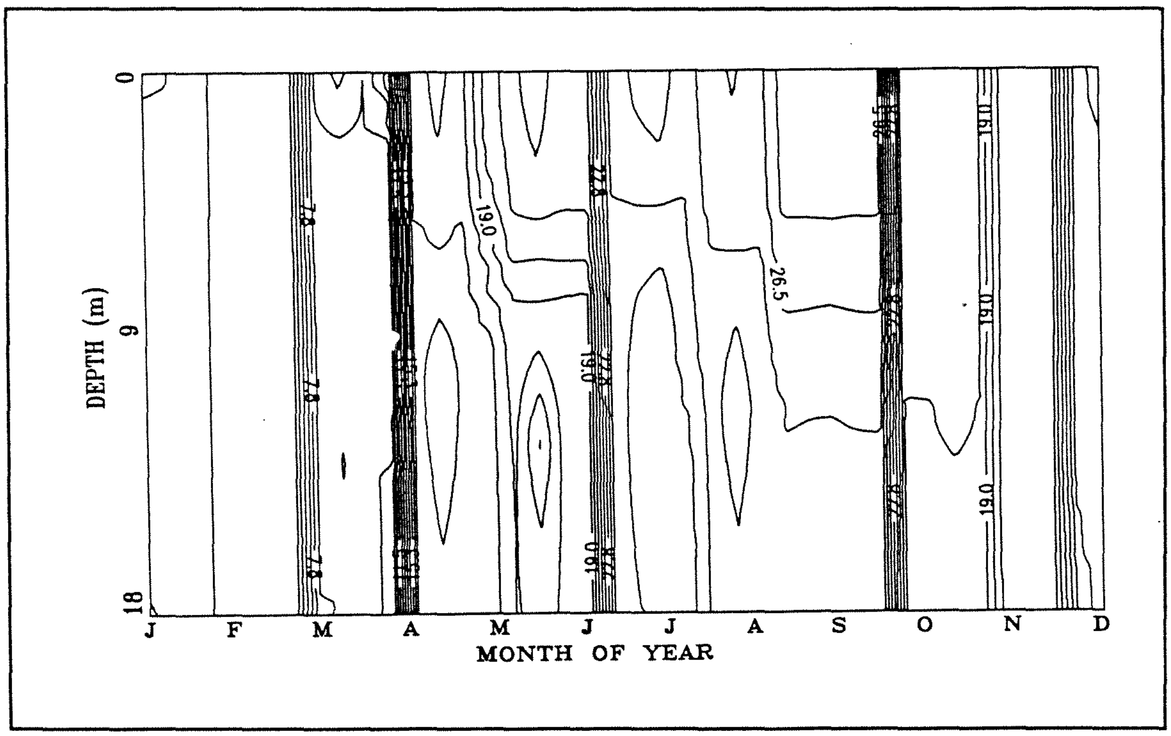


Figure 48. Grand Lake station 2 thermal isopleth, CY89.

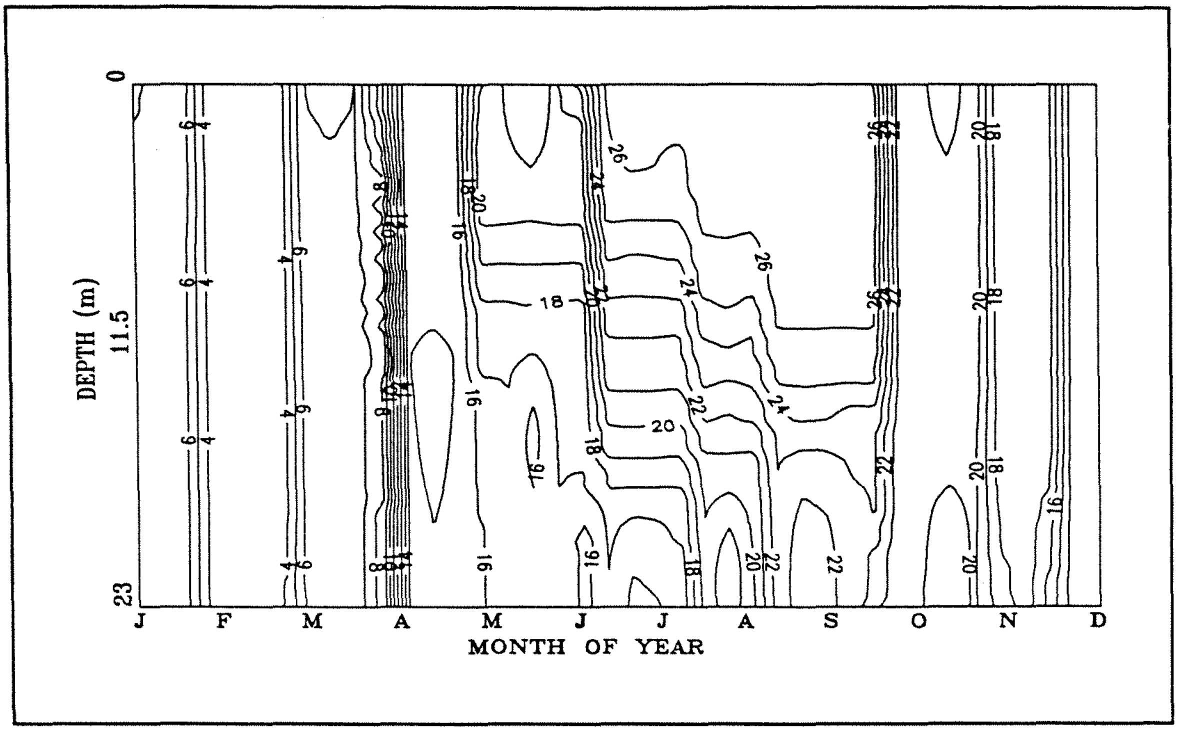


Figure 49. Grand Lake station 3 thermal isopleth, CY89.

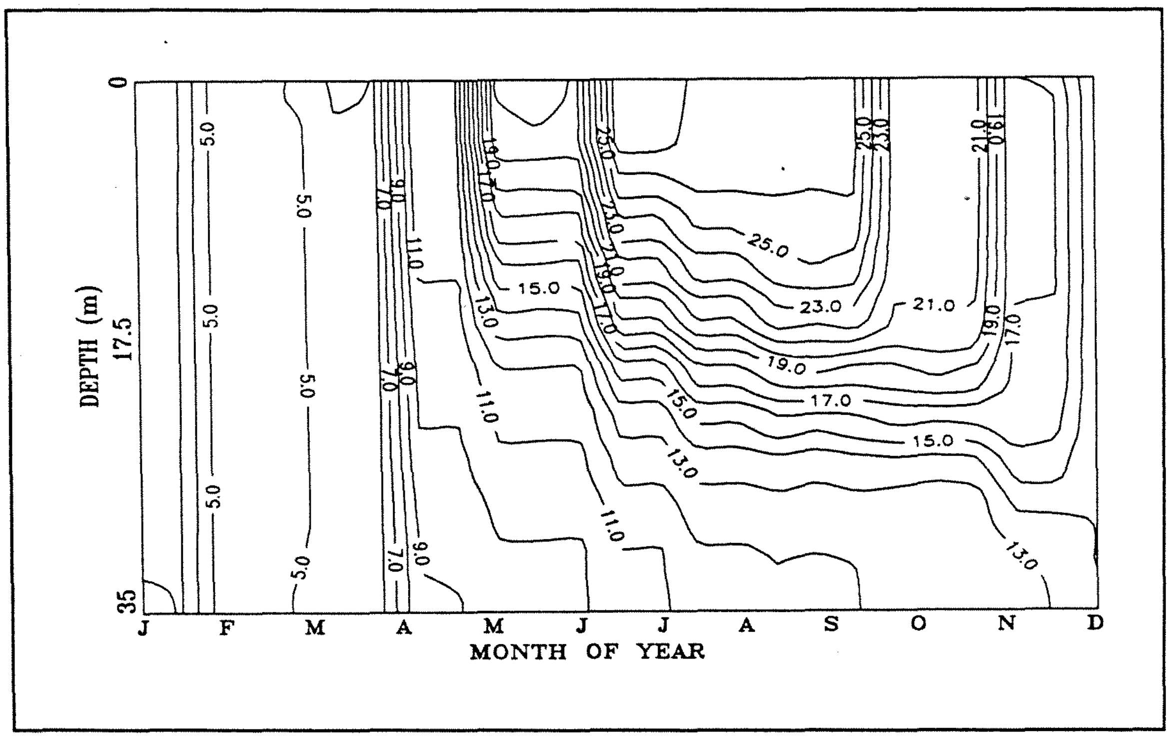


Figure 50. Grand Lake station 4 thermal isopleth, CY89.

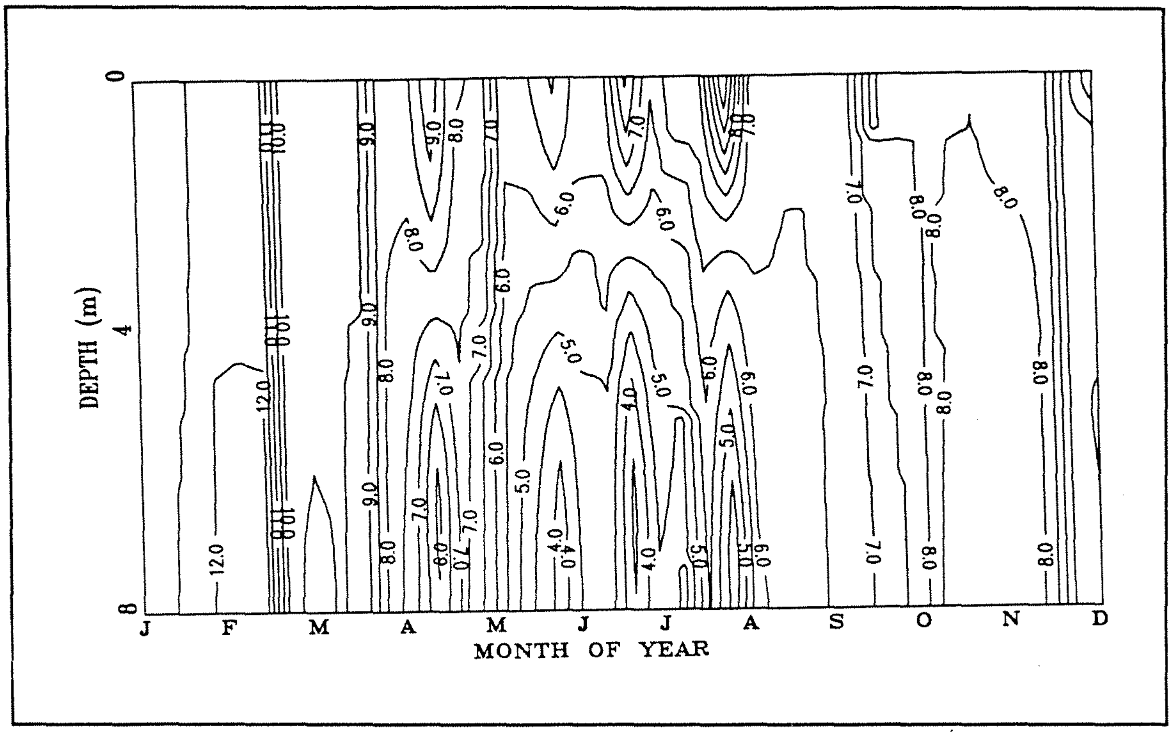


Figure 51. Grand Lake station 1 DO isopleth, CY89.

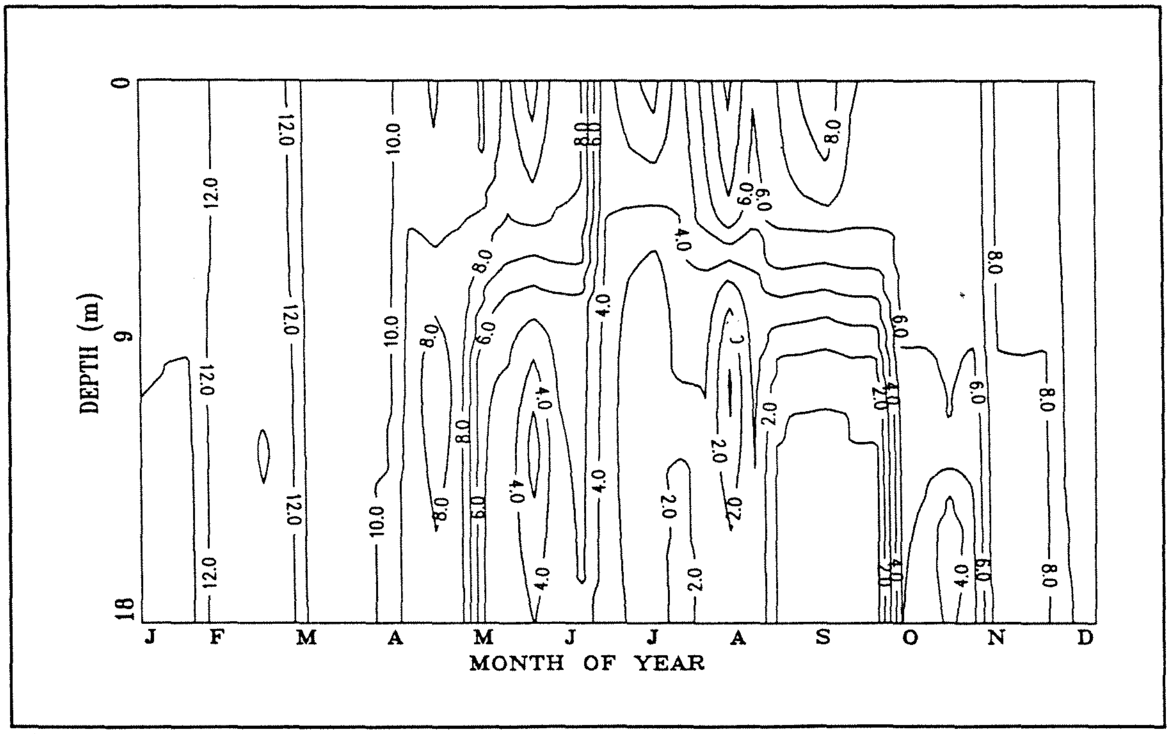


Figure 52. Grand Lake station 2 DO isopleth, CY89.

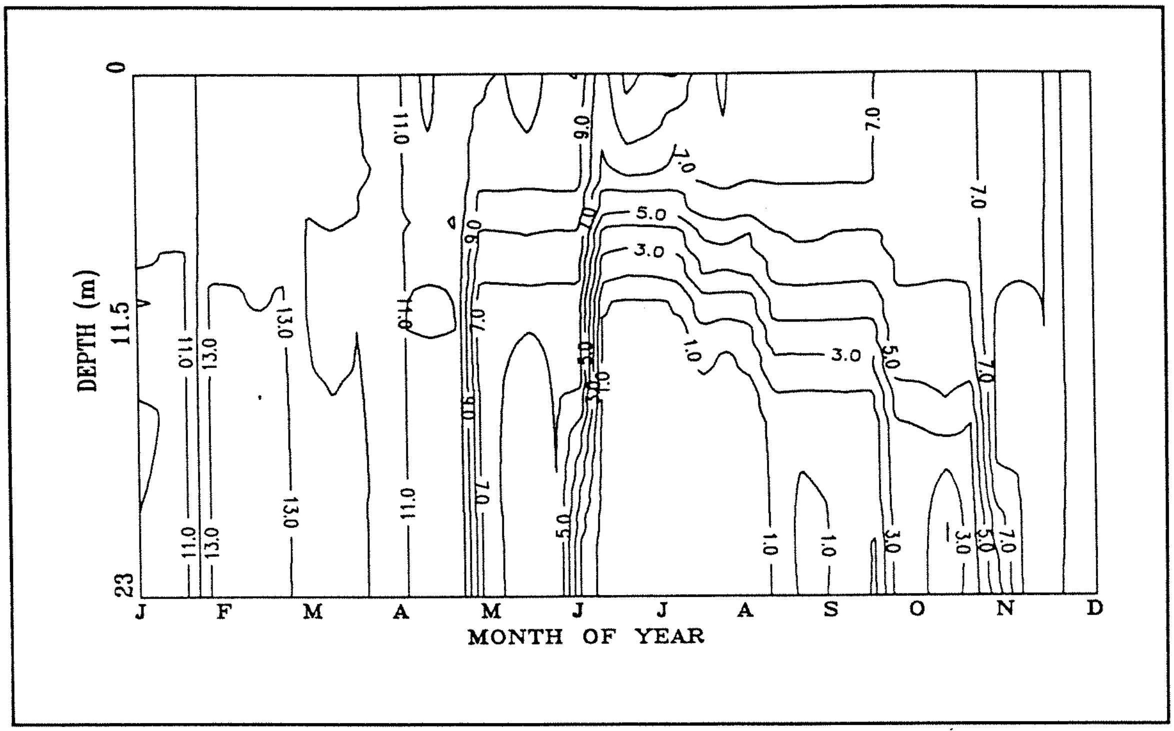


Figure 53. Grand Lake station 3 DO isopleth, CY89.

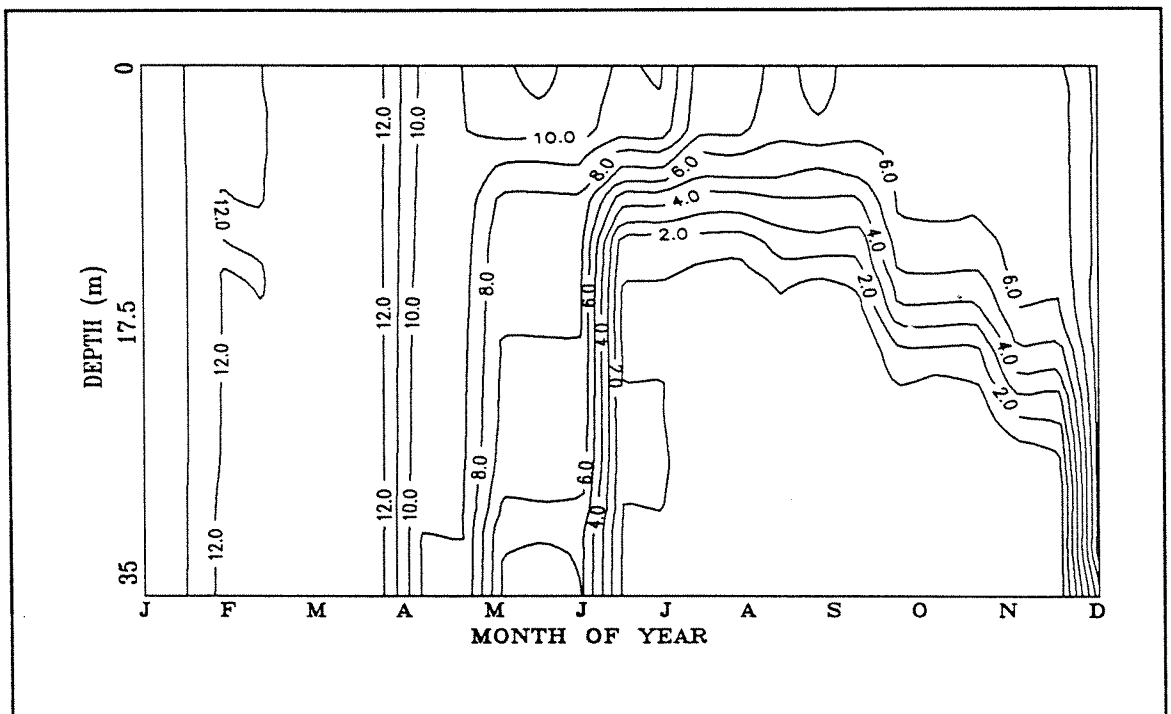


Figure 54. Grand Lake station 4 DO isopleth, CY89.

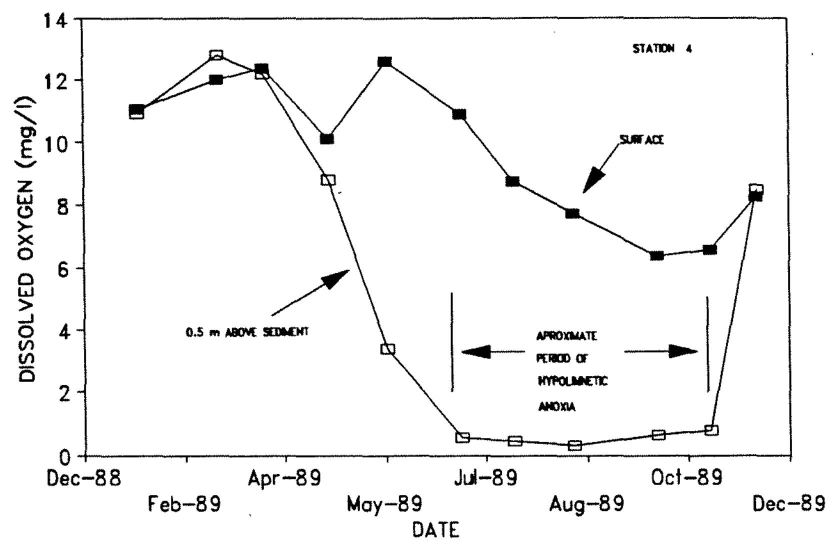


Figure 55. Grand Lake Station 4 Duration of Hypolimnetic Anoxia, CY89.

observed (i.e. ,hypolimnetic DO reached approx 3-4 mg/l levels) (Figure 51).

Conductivity

Conductivity, a measure of ionic activity, at Grand Lake provides an insight to the hydraulic budget. Station 1 has higher conductivity readings, range 340 - 500 $\mu\Omega$/cm, than station 2, range 270 - 370 $\mu\Omega$/cm, station 3, range 280 - 340 $\mu\Omega$/cm, and station 4, range 260 - 360 $\mu\Omega$/cm. This decrease in conductivity is probably due to dilution of the influent waters. Generally, the hypolimnetic waters were found to be more conductive than their respective surface waters.

Station 1 (Figure 56) did not show any significant conductivity stratification regime (i.e., stratification due to differing densities of water with different salinities).

Station 2 shows very weak salinity gradients (with respect to depth) during mid-August to early-September (Figure 57), however, we feel they are insignificant.

Station 3 conductivity profiles remained relatively constant until mid-July, weakly stratified with higher conductivities in the hypolimnion (this is expected because waters with higher salinities have higher densities), and "mixed" in late September (Figure 58).

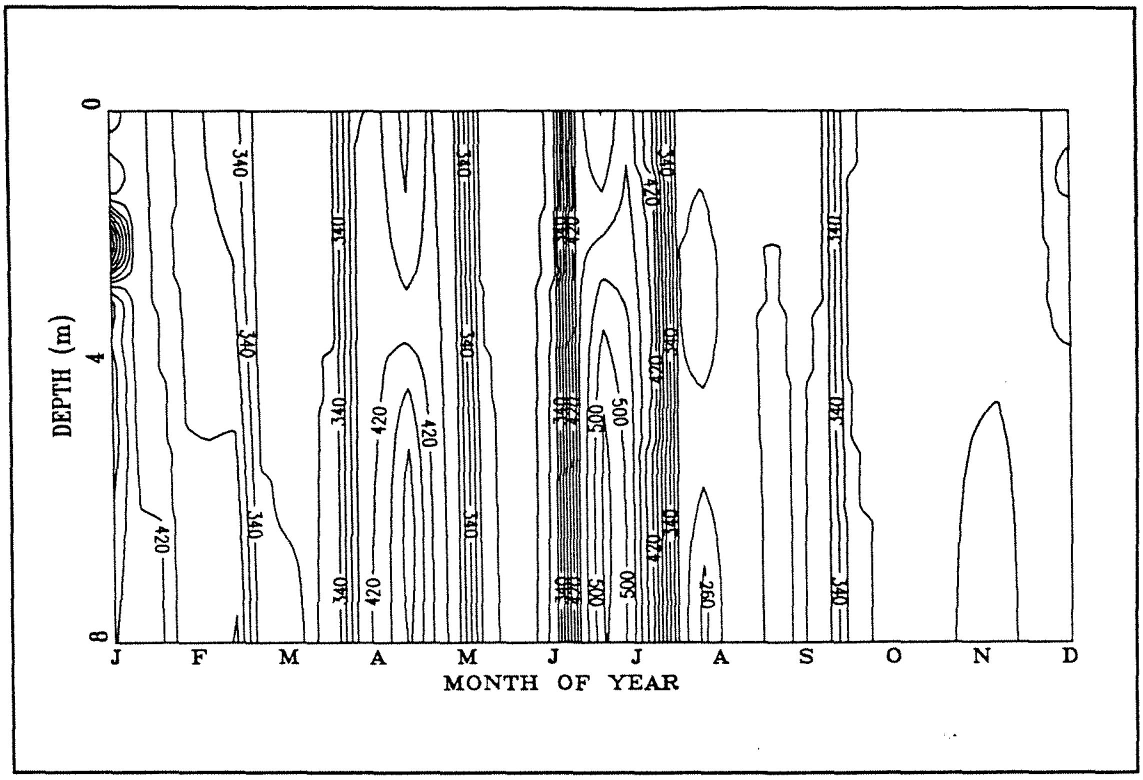


Figure 56. Grand Lake Station 1 Conductivity (μΩ/cm) Isopleths, CY89.

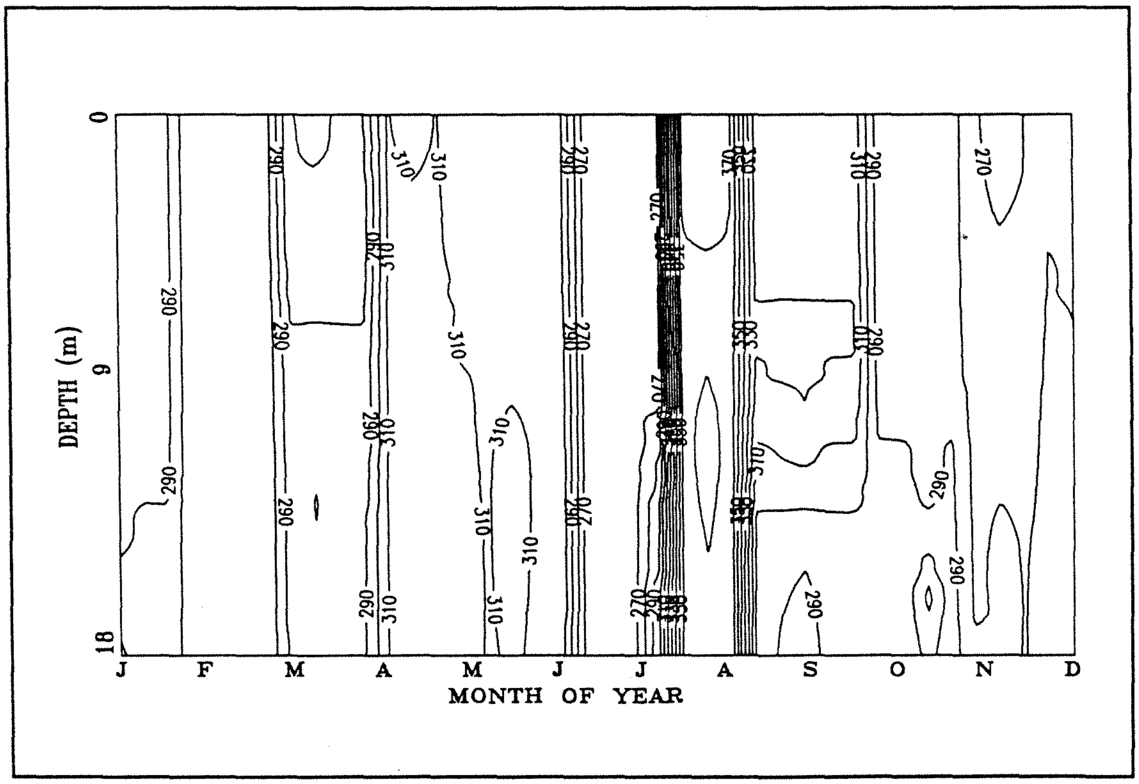


Figure 57. Grand Lake Station 2 Conductivity (μΩ/cm) Isopleth, CY89.

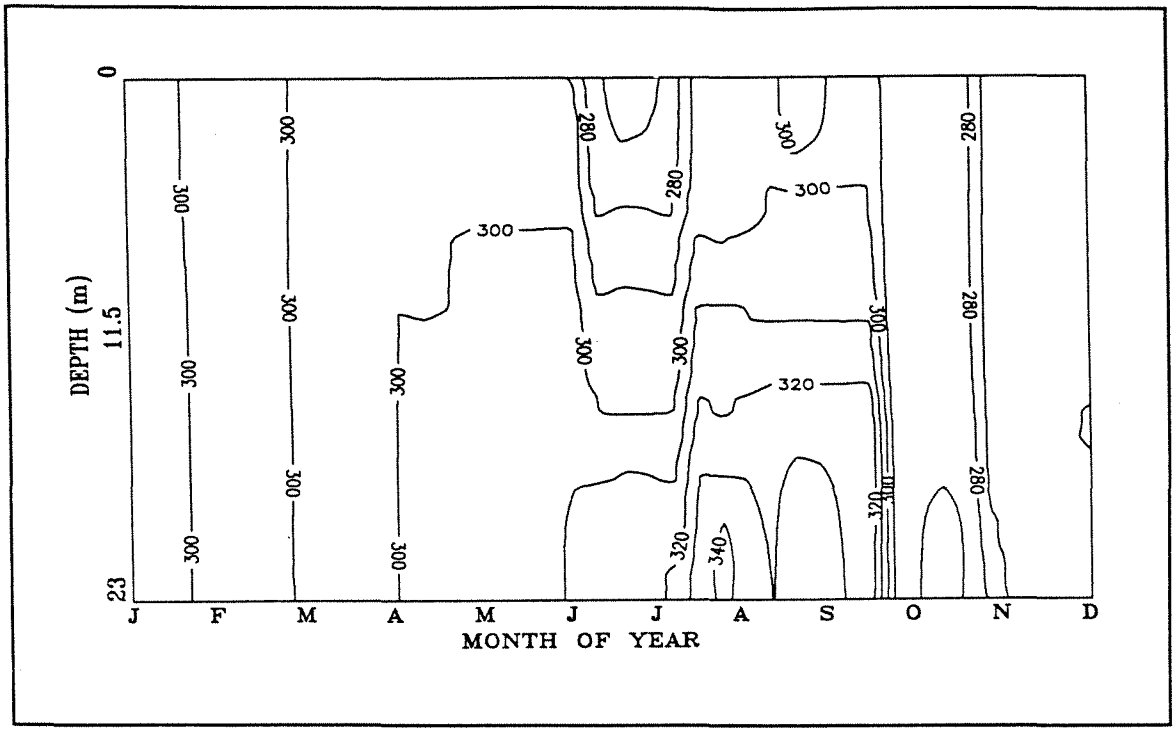


Figure 58. Grand Lake Station 3 Conductivity (μ ohms) Isoplethes, CY89.

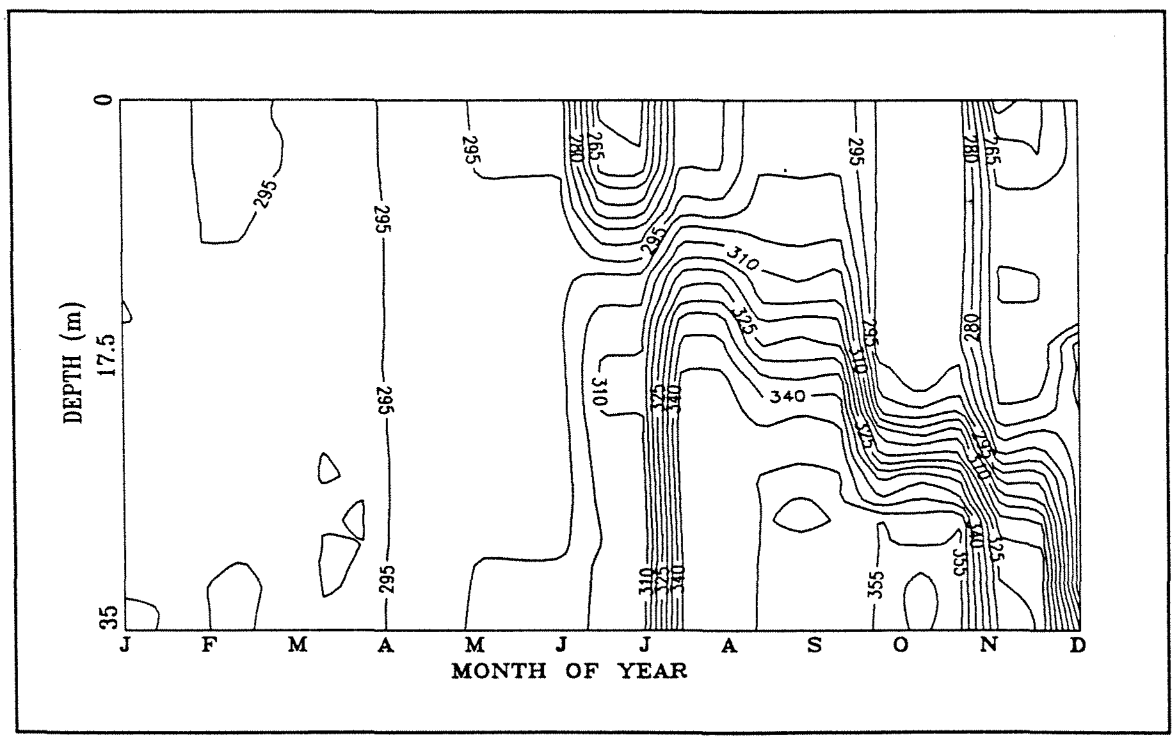


Figure 59. Grand Lake Station 4 Conductivity (μ ohms) Isoplethes, CY89.

Station 4 conductivities showed moderate stratification (with respect to conducivity) beginning ca. early July and "mixing" in late October/early November (Figure 59).

We feel that the higher hypolimnetic conductivities at station 4 are a result of strong thermal stratification, the resulting change in biological/chemical activity, and hypolimnetic withdrawal. The strong thermal stratification exacerbates the conductivity stratification by minimizing mixing and consequently stagnates the hypolimnetic waters. The isolation results in anoxic conditions which leads to lower redox potentials. The hypolimnetic withdrawal probably feeds the hypolimnion of station 4 with the more saline upstream waters. This arrangement also supports our conclusion on higher than normal nutrient flushing rates, discussed later.

Turbidity

Turbidity in Grand Lake shows a distinct decrease progressing from station 1 to station 4 for the period of record (POR) May 1987 - Oct 1990 (Figure 60). The high turbidities (predominantly inorganic turbidity) in the upper end of Grand Lake settle out as the velocity of flow decreases such that turbidity further downstream is predominantly organic turbidity. We feel that the major tributaries (excluding Spring and Neosho) do not seem to contribute significantly to the lake turbidity, because the in-lake turbidities immediately upstream from the tributary are comparable to that of the influent turbidity (Figure 61). However, this does not imply any relative nutrient or particular contaminant load a stream is supplying.

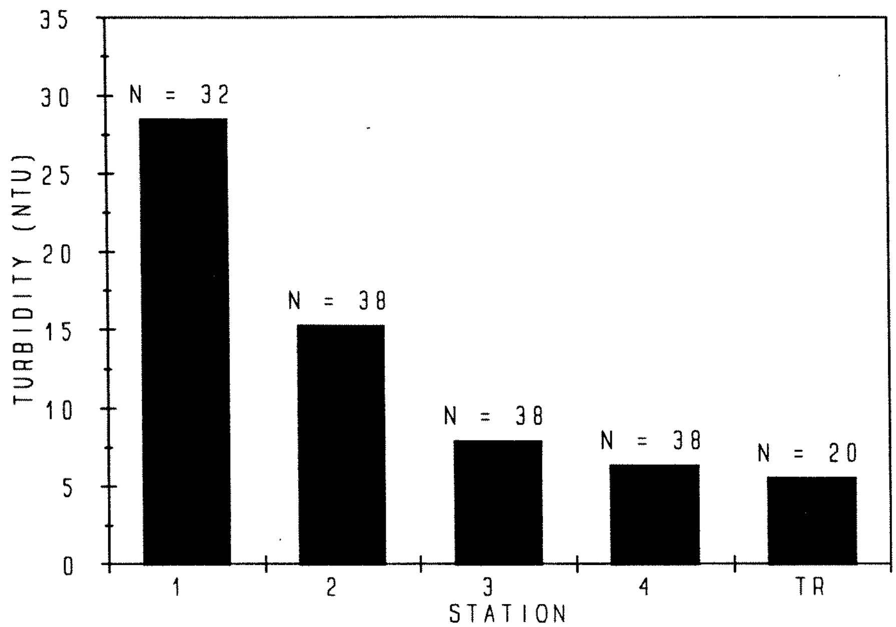


Figure 60. Mean Turbidity at Mainstem Stations on Grand Lake, POR 87 May - 90 Oct.

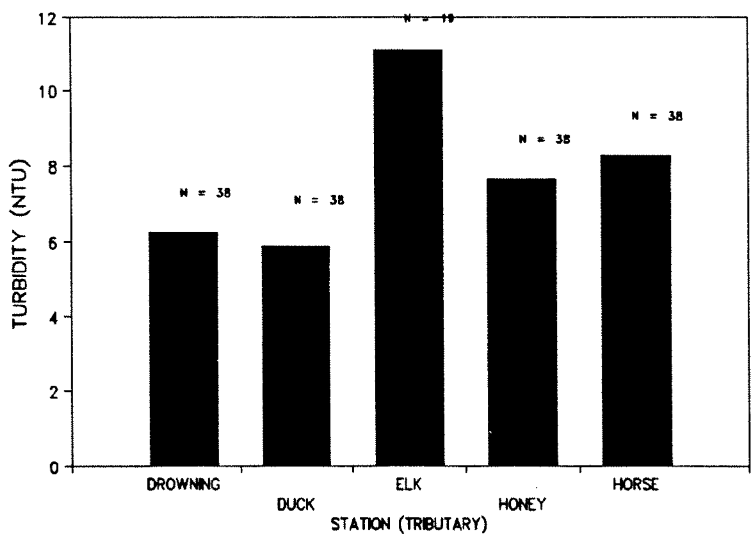


Figure 61. Mean Turbidity at Tributary Stations on Grand Lake, POR 87 May - 90 Oct.

Phosphorus

Grand Lake phosphorus data were derived from two primary sources, Grand River Dam Authority (GRDA) and Oklahoma State University Water Quality Research Laboratory (WQRL).

Soluble phosphorus (*o*-phosphate-P) showed signficant variation and at times denoted high degrees of eutrophy and mesotrophy. These conditions are not unusual for a eutrophic lake. At high degrees of eutrophy, productivity greatly increases (known as algal blooms) in early spring, utilizing the available *o*-P and causing a subsequent decrease in *o*-P. As the algal blooms die and the algal organic matter decomposes, oxygen is involved in the process causing oxygen depletion and a drop in the redox potential. This drop causes a cascade of events that lead to *o*-P recycling and hence an increase in *o*-P at autumnal mixing. The increased *o*-P can be rapidly assimilated (and is in highly eutrophic waters) in the algal biomass yielding an autumnal bloom. The fluctuating *o*-P levels vary from lake to lake. Hence, *o*-P is not the parameter "of choice" for measuring eutrophication.

However, at upstream sites the *o*-P values were high but chlorophyll levels did not reflect the high P load, suggesting that the algae is either light-limited and hence not utilizing the available *o*-P or that there is a toxicity problem. Grand Lake station 1 showed a mean *o*-P concentration 0.056 mg P/l with a range of <0.001 - 1.00 mg P/l (N = 8). These values decreased to a mean value of 0.006 mg P/l ranging from <0.003 to 0.05 mg P/l (N = 8) at station 2S. The most significant decrease was between stations 1S and 2S where mean values went from 0.056 to .006 mg P/l. We feel that most of the *o*-P inputs from the Spring and Neosho rivers are being sedimented out with the clay particles and calcite coprecipitation. However, station 3S showed a mean *o*-P of 0.010 mg P/l ranging from <0.001 to 0.090 mg P/l (N

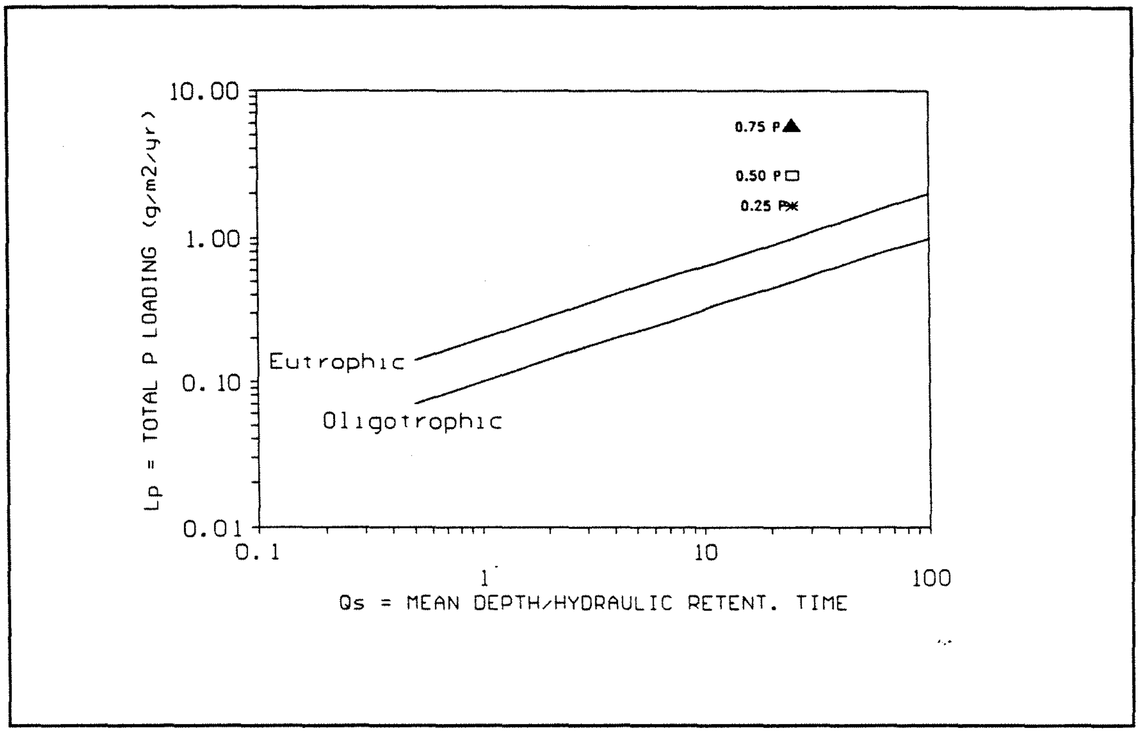


Figure 63. Grand Lake Trophic Status Based on Vollenweider's Loading Plot, WY89.

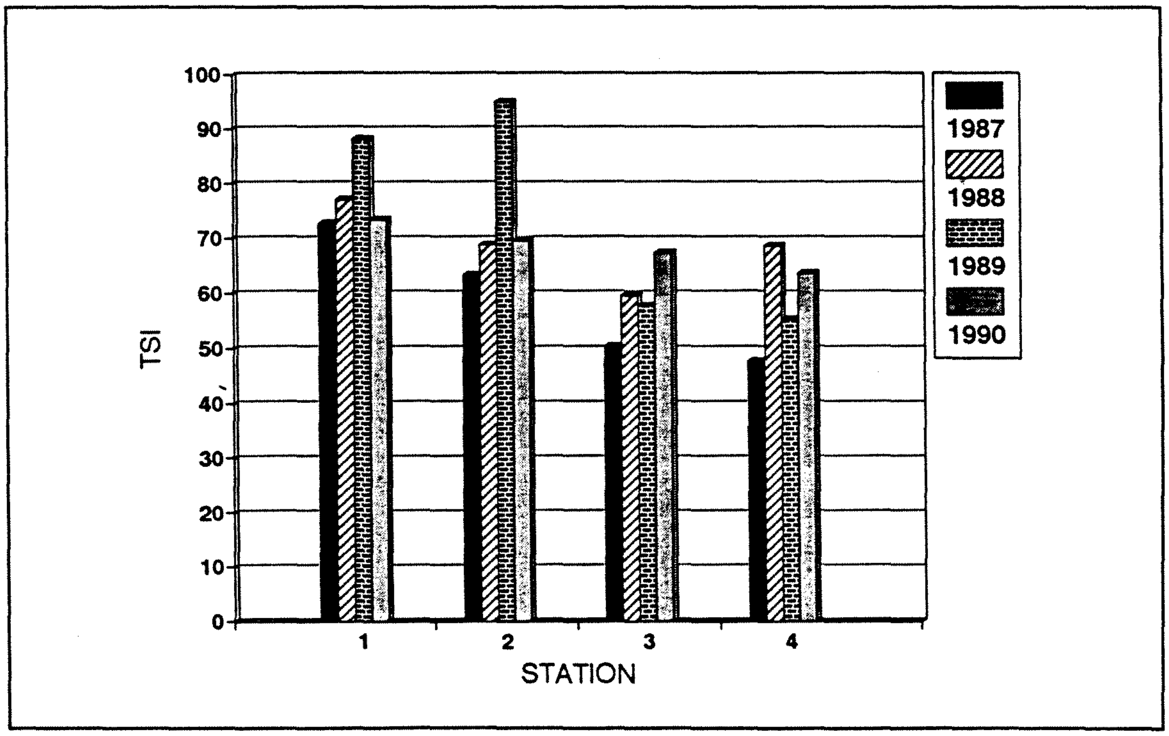


Figure 62. Trophic Status of Grand Lake Based on Carlson's TP criteria.

= 9). We further feel that this is predominantly due to shoreline anthropogenic inputs, especially at the lower end. Station 4S showed a lower value in *o*-P, probably effects of dilution and algal utilization.

The bottom samples (0.5 m above sediment) from the 4 mainstream stations, except station 1, showed substantially higher mean *o*-P values than their respective surface samples. We feel that these data suggest significant sediment release of phosphorus and indicate the severity of eutrophic conditions in Grand Lake and its potential to develop hypereutrophic conditions.

Mean values of TP at station 1 were higher than those at stations 3 and 4 (Figure 64). Station 2 had the highest mean value for TP. We feel that the decreasing turbidity from sedimentation between stations 1 and 2 allows for increased primary productivity and thus more uptake of the available phosphorus which originates from the Spring, Neosho, and Elk rivers. The

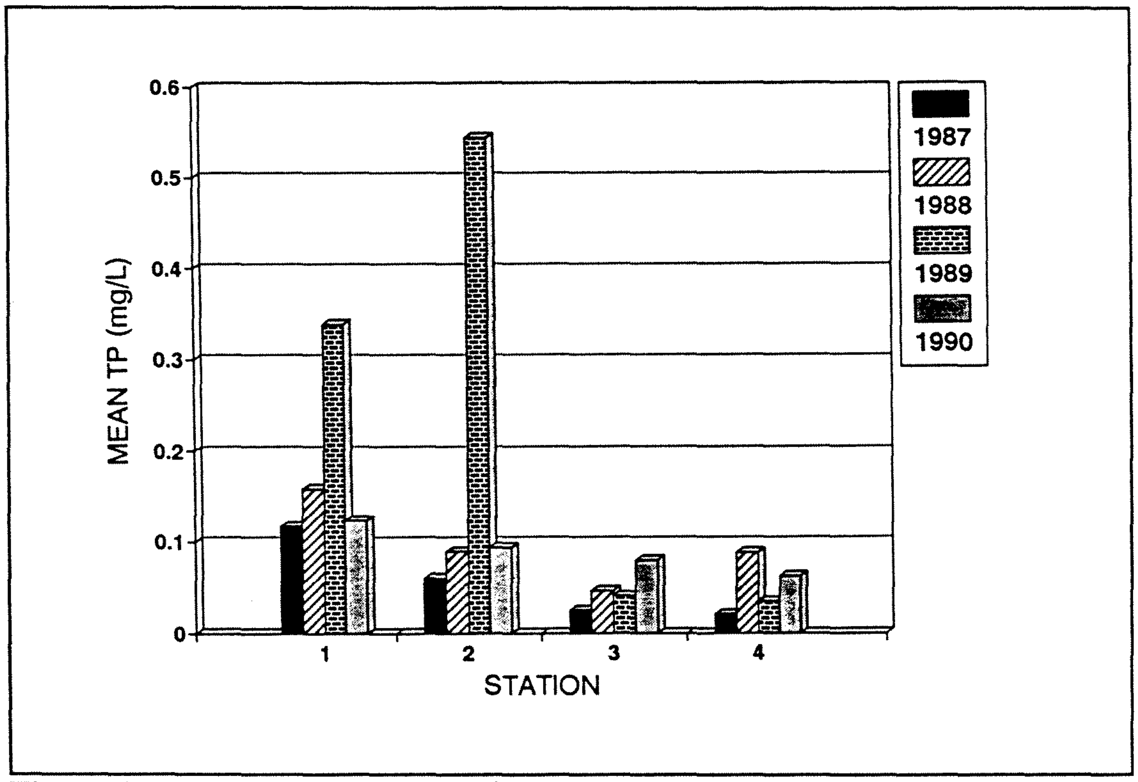


Figure 64. Mean Total Phosphorus Values at Stations 1-4, POR 87 May - 90 Oct.

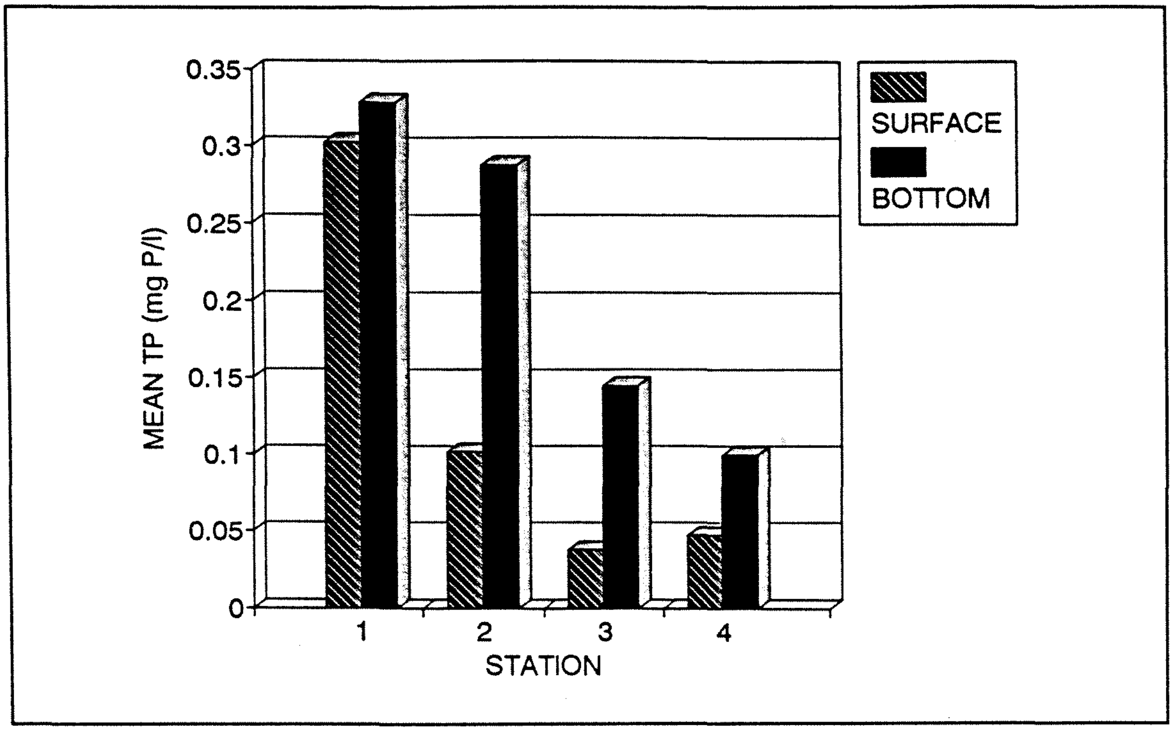


Figure 65. Comparison of Surface to Bottom TP Means in Grand Lake, POR 89 May - 90 Oct (data from WQRL).

average TP for Elk River exceeded the average TP for station 2 and hence, theoretically, could contribute to increased productivity.

A phosphorus loading model was constructed from the data on Spring and Neosho rivers combined and Elk River. Flow data were obtained from USGS (1990) Water Resources Data Oklahoma Water Year 1989. The TP values from GRDA were used as the loading concentrations. The flow and TP data were ranked and applied on the basis of quartile distributions (i.e. 0.25, 0.50, and 0.75 percentiles). The variability of the surface area and mean depth of Grand Lake were not available and assumed constant at 1.88 X 10^8 m^2 and 10.9 m, respectively. The results indicate eutrophic conditions at the three ranks used when plotted on Vollenweider's (1969) loading/trophic status delineation (Figure 61).

Most models of eutrophication use total phosphorus (TP) as the input parameter. This form measures the combined *o*-P and that fraction bound in organic matter. For this reason, TP will be used as the trophic state evaluation input parameter. Carlson's (1977) criteria utilizes surface total phosphorus, chlorophyll a, and Secchi disk depth. chlorophyll a is not used here due to the light-limitation in the upper end. Secchi disk values are biased to eutrophy due to increased suspended sediment loads, hence the use of TP. The TP indices indicate eutrophic conditions at all stations (Figure 62).

A comparison of bottom to surface TP values, also reflects eutrophy. As eutrophication progresses, the P is recycled from the sediment. The difference in surface to bottom TP values indicate eutrophy (Figure 65). The largest differences were observed at stations 2, 3, and 4.

To estimate the potential reduction of phosphorus loads by eliminating the anthropogenic inputs (shoreline only), we ran Reckhow's (1988) model with stochastic input and predicted the resultant in-lake phosphorus concentration. The results provide a means to estimate the phosphorus inputs of the adjacent basin area (i.e. ,that portion not draining into the Spring and Neosho rivers). The model is given as:

$$P = \frac{P_i}{1 + k_P \tau_w}$$

where P is the predicted in-lake TP concentration (mg/l), P_i is the annual average influent concentration (mg/l), k_P is the phosphorus trapping coefficient, and τ_w is the hydraulic retention time (yrs). This equation was programmed in BASICA and allowed to simulate the 3 years of record with 365 iterations per year. The influent phosphorus concentration was stochastically derived from the population of each year's measured TP concentrations at station 1. We chose to compare the predicted values to surface values (data from GRDA) because the bottom values would bias the estimate due to elevated levels from P recycling. The difference is the theoretical estimate of the adjacent inputs to the lower end of the lake. It is noted, however, that this is an empirical model and thus may not reflect a single lake's responses, but was calibrated on data from southeastern reservoirs. Hence, we feel that this model more accurately reflects Grand Lake than would the models calibrated on natural lakes.

The results of predicted in-lake phosphorus concentrations were generally lower than those observed (Table 42). The values predicted for the years 1987 and 1989 almost exactly predicted the observed values. However, the predicted values for the years 1988 and 1990 indicate adjacent inputs equivalent to 53 μg P/l and 21 μg P/l, respectively.

If complete elimination of adjacent phosphorus sources were attained, the resulting trophic status would remain eutrophic according to Carlson's and Vollenweider's (1968) criteria, albeit the lake would approach mesotrophic conditions (i.e. $P < 20$ μg/l). We feel that this prediction is at a minimum and the benefits from a phosphorus elimination plan will exceed that predicted for two reasons. One is that higher sedimentation rates in Grand Lake than those used in Reckhow's calibration would yield a lower actual P concentration than predicted (i.e., the model would overestimate P at station 4. Secondly, the tailrace P levels are higher than those at station 4, thus increasing the nutrient flushing rate.

Nitrogen

Nitrogen and phosphorus are the two elements that are usually algal growth limiting factors. Nitrogen is the second most important element in algal growth. When the algae use up one source (N or P) that source then becomes limiting. Many studies that attempt to describe algal nutrient limitation have been conducted and the only salient inference that has been made is that of nitrogen/phosphorus (TN/TP) ratios used as indices of limitation. Most limnologists use a critical value of about 15. If the value

Table 42. Comparison of Predicted and Observed TP Levels in Grand Lake, POR 87 May - 90 Oct.

Year	Observed (annual mean)	Predicted (annual mean)	Estimated inputs (Pred. - Obs.)
1987	0.021	0.026	-0.005
1988	0.088	0.035	0.053
1989	0.035	0.036	-0.001
1990	0.062	0.041	0.021
Cumulative	0.052	0.043	0.009

falls below 15, nitrogen is in short supply and hence inferred as the limiting nutrient. In contrast, if the ratio is larger than 15, phosphorus is in short supply and hence inferred as the limiting nutrient. Although source control of nitrogen is difficult, its importance and implications in algal blooms merits an examination.

Grand Lake showed a decrease in annual mean nitrate-N (NO_3-N) from station 1 to station 4, with surface concentrations generally lower than their respective bottom concentrations (Figure 66). The longitudinal decrease probably results from the dilution of the inflowing waters. The higher bottom values probably represents increased decomposition at the sediment water interface thus releasing organic nitrogen into the hypolimnion. Higher assimilation rates from increased epilimnetic algal productivity also may contribute by decreasing the epilimnetic concentrations. All values except stations 3S and 4S exceed Sawyer's (1947) limit of 300 μg/l N, which related a high probability of the development of nuisance phytoplankton populations during the growing season.

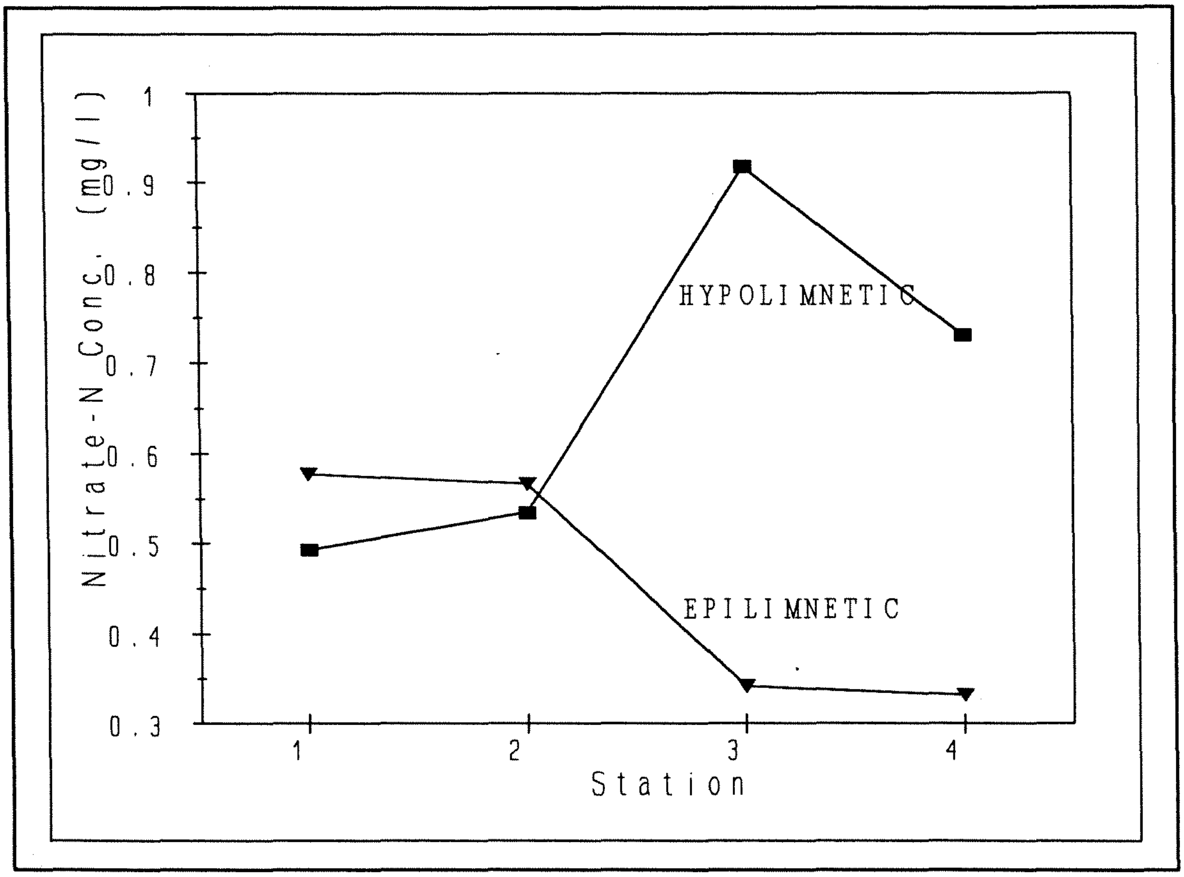


Figure 66. Grand Lake Annual Mean Nitrate-N (NO_3-N).

Total Kjeldahl Nitrogen (TKN), organic-N + ammonia-N, levels in Grand Lake showed a similar longitudinal pattern with the largest concentration occurring at station 1, mean TKN = 18.6 mg/l, and decreasing toward station 4, mean TKN = 9.3 mg/l. The relative contributions of TKN by the major tributaries (excluding Spring, Neosho, and Elk rivers) were comparable to that of the in-lake concentrations immediately upstream from their confluences (Figure 67). The Elk River showed TKN concentrations slightly higher than the in-lake concentration at its confluence. This nitrogen load represents an increased potential for accelerated eutrophication because it joins the main lake at the transition zone, which reflects the highest productivity. The high primary productivity is presumably due to high influent nutrient levels (especially N and P) and increased light penetration (Thornton,

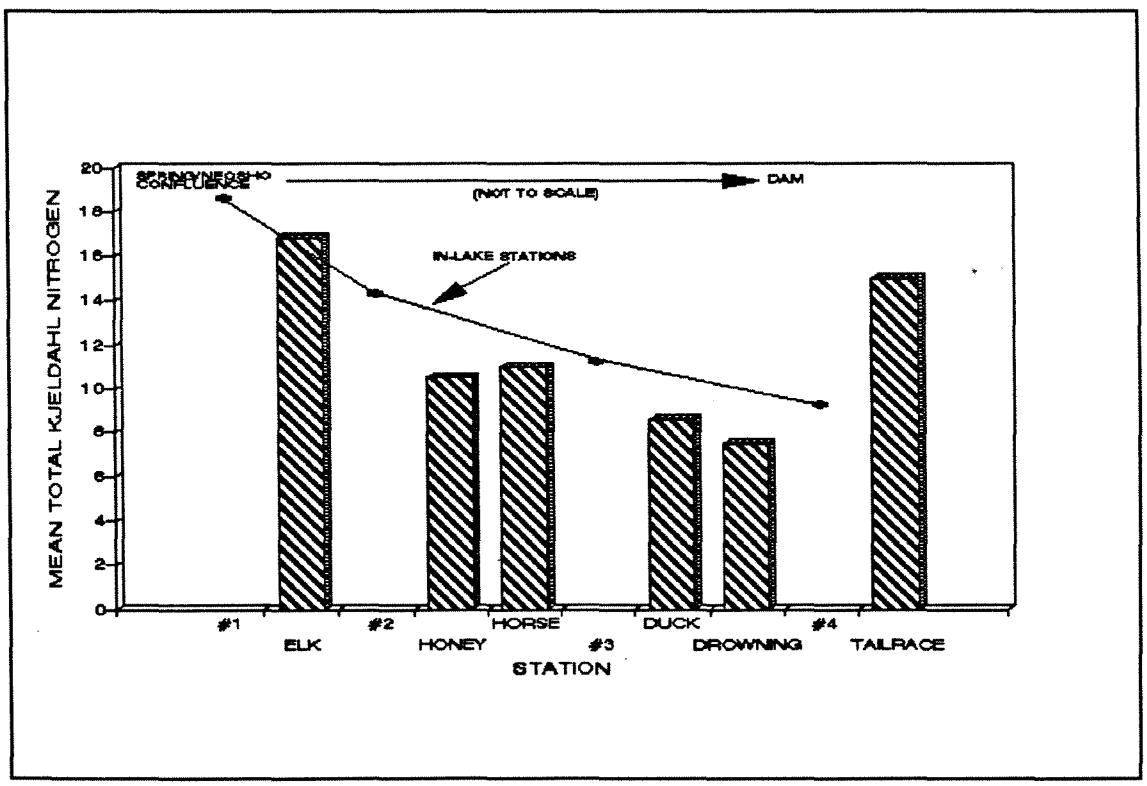


Figure 67. Grand Lake Mean TKN Values, for POR 87 May - 90 Oct (data from GRDA).

1982). The higher TKN values from the Elk River coupled with its significant hydraulic contribution represents an increased potential for accelerated eutrophication and thus merits a monitoring regime in the future. The remaining tributaries, i.e. Horse, Honey, Drowning, and Duck creeks, did not contribute to increased TKN values and thus are considered insignificant, albeit N-reduction plans such as implementation of BMPs could theoretically reduce in-lake nitrogen levels.

Total nitrogen to total phosphorus ratios have been used as an index to assess which factor, N or P, is limiting algal growth (Schindler 1977). Although we were not able to construct TN/TP ratios due to lack of TKN data, we are able to make comparisons of nitrate-N/total phosphorus ratios with those calculated by Okla. State Dept. of Health (OSDH 1982) and EPA's national eutrophication survey (NES) (EPA 1974) at nearby stations (Table 43). OSDH found that phosphorus had increased at 4 out 5 sites from 1974 - 1982 where comparative data were available. Grand Lake station 3 is located immediately below the confluence of Horse Creek. The nitrate-N/TP ratio of Horse Creek calculated by OSDH in 1982 was 6.2 compared to our station 3 value in 1989 of 11.6. Station 4 is immediately below Duck Creek. The OSDH (1982) nitrate-N/TP ratio was calculated as 4.9 compared to our value at station 4 of 14.7. Our calculated values were generally higher than those found by OSDH. We feel that increased nitrogen loadings are responsible, because the phosphorus trends in the major tributaries have historically increased and hence could not have contributed to higher nitrate-N/TP trends. The nitrate-N/TP ratios calculated by WQRL also showed an increase from station 1 to station 4. We feel that this only reflects the phosphorus coprecipitation and clay particle adsorption processes that remove phosphorus from the water column.

Table 43. Nitrate-N/TP Ratios for Grand Lake POR 89 Jun - 90 Sep, (data from WQRL).

Station		Nitrate-N/TP ratio TP Mean	Min	Max	N
#1	Surface	3.2	0.2	505	8
#1	Bottom	2.6	0.6	4.9	7
#2	Surface	5.3	3.3	9.8	7
#2	Bottom	2.8	0.0	5.1	7
#3	Surface	11.6	0.0	41.3	6
#3	Bottom	10.4	0.2	53.4	7
#4	Surface	14.7			
#4	Bottom	12.8	2.7	34.3	6

Chlorophyll

Chlorophyll-a density provides an estimation of algal standing crop, albeit it does not provide information on community structure. Many limnologists use chlorophyll-a densities for inter- and intralake comparisons; such will be the case with this study.

Current data - Water samples at the 4 mainstem stations were collected at 0.5 m below the surface and placed in 250 ml opaque HDPE containers. These samples were immediately placed on ice and returned to the lab for chlorophyll-a analysis. The method of analysis was as per American Public Health Association *Standard Methods for the Examination of Water and Wastewater* (1980). The filtration and acetone extraction phases were performed on all samples within 48 hours of collection. Triplicate samples collected at random, field blanks, and procedural blanks were used for experimental error estimation and quality control. All values were corrected for phaeophytin pigments.

The most salient feature of the chlorophyll data obtained by WQRL is the consistent decrease in chlorophyll densities toward the lower reaches of the lake. On all dates sampled, the highest chlorophyll a densities were at either station 1 or 2 (Table 44). Generally, station 3 chlorophyll densities were larger than station 4. However, on 10 Aug 89 station 4 had a slightly higher

Table 44. Chlorophyll-a (μg/l) Data for Grand Lake Mainstem Stations (Data from WQRL)

	STATION			
Date	1	2	3	4
06 Jun 89	18.2	1.7	8.6	8.2
21 Jun 89	38.3	9.8*	7.9	<0.1
21 Jul 89	0.3*	1.6	1.2	0.7
10 Aug 89	32.3	46.5	13.5	14.2*
07 Sep 89	4.7	5.8**	---	---
02 Oct 89	55.9	19.9	7.0	18.0*
10 Jul 90***	21.6	37.6	17.6	---
23 Aug 90	30.5*	17.9	10.8*	9.6*

* = Mean value with n = 3.
** = Transect value for Hickory Point to Sailboat bridge.
*** = Transect value with n = 6.

chlorophyll density than station 3, but we feel it is insignificant when compared to stations 1 and 2 on the same date. On 02 Oct 89, the chlorophyll level at station 4 was almost twice as high as that at station 3. This may represent a slight autumnal bloom due to the increased availability of nutrients from fall mixing, albeit complete mixing had not yet occurred but breakdown of thermal stratification had begun.

Due to the potential nutrient loads of the Elk River (discussed earlier), an extensive sampling trip on 10 Jul 90 was conducted to estimate the impact the Elk River nutrient loads were having on the phytoplankton. Samples were taken at station 1, approximately 0.5 mi north of the Elk River confluence, Elk River confluence, Elk River Bridge on State Highway 10, station 2 and station 3. The results showed the highest chlorophyll densities at the Elk River confluence, which exceeded those typically observed at the 4 mainstem stations (Table 45). We feel that the high nitrogen load from the Elk River coupled with the available phosphorus and increased light penetration is primarily responsible for these excessive chlorophyll densities. Hence, we feel that the Elk River should be monitored for nitrogen and chlorophyll levels in the future.

Table 45. Chlorophyll-a (μg/l) Data from WQRL Sampling Survey on 10 Jul 90

Station	Chlorophyll-a
#1	21.6
~0.5 mi North of Elk River	25.2
Elk River confluence	39.5
Elk River Bridge (@HW 10)	39.2
#2	37.6
#3	17.6

Historical Comparison - The 1974 NES study included chlorophyll analyses for seven stations on Grand Lake. It is noted, however, their numbering is exactly opposite GRDA's, i.e., EPA's #7 approximates GRDA's #1. EPA's in-lake stations with GRDA's stations in parenthesis were 1(4), 5(2), and 7(1). Chlorophyll densities, as reported by EPA-NES (1974) study, showed the same trend but were significantly lower than this study's values (Table 46).

Chlorophyll maxima - Summer maxima of chlorophyll densities are often more useful indicators of water quality than mean chlorophyll densities because they potentially represent algal bloom conditions.

Station 1 showed chlorophyll maxima on 21 Jun 89, [chl] = 38.3 μg/l, and 02 Oct 89, [chl] = 55.9 μg/l. This is in accordance to eutrophic conditions where a algal bloom occurs in the spring and late fall ca. fall mixing. However, these hypothesized trends are based on nutrient availability. Station 1 typically denotes light limitation and thus should not be affected by nutrient levels. The explanation of this occurrence at station 1 is yet to be determined.

Station 2 showed two chlorophyll maxima on 10 Aug 89, [chl] = 46.5 μg/l, and 10 Jul 90, [chl] = 37.6 μg/l. The Aug 89 peak might be explained by abnormal weather which may have caused the lake to partially mix thus recycling hypolimnetic nutrients into the epilimnion. A slight fall peak was observed on 02 Oct 89, possibly indicating the fall bloom. The cause of the 10 Jul 90 peak remains unexplained.

Station 3 showed two chlorophyll maxima on 10 Aug 89, [chl] = 13.5 μg/l, and 10 Jul 90, [chl] = 17.6 μg/l. The explanation of these maxima remains as those for station 2.

Station 4 showed two chlorophyll maxima on 10 Aug 89, [chl] = 14.2 μg/l, and 02 Oct 89, [chl] = 18.0 μg/l. This station also showed a disproportionately high value on 06 Jun 89, [chl] = 8.2, probably representing the spring bloom. The cause of the 10 Aug 89 peak remains as for stations 2

Table 46. Comparison of EPA-NES (1974) and WQRL Mean Chlorophyll Densities in Grand Lake

Station (EPA-NES Station)	Chlorophyll-a ($\mu g/l$)	
	WQRL	EPA-NES
#1 (07)	24.9	13.5
#2 (05)	14.2	6.5
#3 ( )	7.6	No Data
#4 (01)	8.2	4.0

and 3. The 02 Oct 89 peak probably reflects the increased nutrient availability (especially P) from fall mixing.

Summary - Chlorophyll a densities in Grand Lake denote eutrophic conditions as delineated by Wetzel (1983). The major concern in this respect is that the seasonal trends, i.e., spring and fall peaks, exemplify eutrophication and thus control of the causal factors is warranted.

TASK 11e: Sediment Analysis

OBJECTIVES: The objectives of this study were to:

1) estimate the levels of cadmium, lead and zinc in gizzard shad by liver and kidney analyses via atomic absorption,
2) relate fish residue concentrations with levels of dissolved metals in the water column at surface and bottom depths to quantify the bioavailability of these metals,
3) evaluate the effects of Grand Lake water column samples upon survival and reproduction of Ceriodaphnia dubia, and
4) evaluate the effects of Grand Lake sediment extracts upon survival of Daphnia magna, Hyallela azteca, Ceriodaphnia dubia and survival and teratogenicity of fathead minnow, Pimephales promelas embryos.

REVIEW OF THE LITERATURE : Heavy metal contaminants in aquatic systems undergo two major routes of transport: in solution in the water column and in association with suspended particulates. Heavy metals may be associated with particles in the following ways: adsorbed at particulate surfaces, carbonate-bound, occluded in iron and or manganese oxyhydroxides, associated with organic matter (living or detrital), sulfide-bound, or matrix-bound (Tessier and Campbell 1987). In addition to the suspended particulate phase, metals in natural water systems may be partitioned in two other phases: aqueous, and bottom sediment, all of which may be available to organisms. Sediments can act as temporary or semi-permanent storage phases during these transport processes. In the latter phase, sediments can act as contaminant sources after the water column pollution has declined and the long-term biological effects of this process are not well characterized.

Discussions of the bioavailability of metals must include a description of the various forms taken by the metal. This requires information about the metal content of a particular water sample to be partitioned into dissolved and suspended metal loads.

The total metal concentration in aquatic systems is made up of ionic, colloidal, complexed and particulate forms. Two analytical techniques may be applied to the problem of metal speciation, anodic stripping voltammetry and ultrafiltration and dialysis. The former separates metal species into electroactive, (aqueous ions and labile complexes) and electroinactive (organic complexes and colloidal species) components. Filtration or dialysis separates metal species based on size. Conventionally, the portion passing through a 0.45 um diameter membrane filter is considered to contain the free metal ion and small complexes with organic ligands such as amino, fulvic and humic acids.

It is this latter portion of free ions and weakly complexed species that is considered to be bioavailable while the non-labile portion of inert metal complexes is considered to be biologically unavailable (Florence and Batley 1980). Thus, the availability of heavy metals for biota is closely related to the chemical species both in solution and in particulate matter. Little is known, however, about the chemical association of metals in suspended materials and sediments.

Recent data concerning the toxicity of metals to aquatic organisms show effect levels over many orders of magnitude of total metal load, suggesting that total metal content is not an indicator of metal bioavailability. Instead, metal toxicity in an aquatic system is usually a function of the free or ionic metal form and some hydrolyzed species. In sediment, the issue of bioavailability becomes more complex.

In any case, for benthic invertebrates such as C. tentans and H. azteca, toxic effects can be expected to occur only if the chemical concentration is high enough in the sediments such that the equilibrium interstitial water concentration due to desorption is equal to or greater than the concentration demonstrated to cause an effect in a water exposure sediment-free test (Adams et al. 1985).

Sediments may be characterized with respect to metal speciation. Methods include fractionation by size and physicochemical methods. The metal oxide, organic calcium carbonate coatings or phases of sediment, along with ion exchange sites, are responsible for the sorption of metal ions from solution.

Adding to the difficulty of measuring sediment toxicity, it has been found that contaminants absorbed to naturally aged sediments have a readily desorbable labile fraction and a fraction resistant to equilibrium. This latter fraction requires a longer period of time to reach desorption equilibrium than lab-spiked sediments (DiToro and Horzempa 1982).

Jenne and Luoma, (1977) in a study of the particulate phase, reviewed the physicochemical partitioning of metals, in particular, cadmium. It was suggested that the most likely sinks for this metal were oxides and organic substances. They also found that the bioavailability of cadmium is controlled by the equilibrium concentrations in the sediment-water interface. This equilibrium is maintained by sorption-desorption and dissolution-precipitation reactions.

McCormick (1985) obtained sediment leachates from Grand Lake sediment samples extracted with reconstituted water at pH values of 3, 4, 5, 6, 7, 8 and 9. McCormick found that lead extractibility was least sensitive to pH while zinc extractibility was very sensitive.

Releases of metals from sediment may occur naturally, or as a result of human activity. Examples of the latter include dredging, land disposal of contaminated sediments and pH changes due to acid rain.

Examples of the former cited by Forstner and Prosi (1979) include an increase in salinity, of concern in the estuarine environment, a decrease in pH, the introduction of synthetic complexing agents as substitutes for phosphates in detergents, the action of microbes and physical effects such as erosion, dredging and bioturbation. Natural release mechanisms are dependent upon the physicochemical conditions of both the sediment and the water column, since contaminants are released from sedimenting particles during their fall through the water column. Crucial to release processes is the position of the interface between oxic and anoxic strata. In homogeneous aquatic systems, this interface or redoxcline is located in the sediments and in the water column for some stratified lakes (Salomons et al. 1987).

The sediment-water complex can be divided into three layers: the oxic zone, the anoxic zone and the intervening layer, the redoxcline. The oxic zone may extend into the sediment of well-mixed aquatic systems and it is here that degradation of the sediment particles occurs. Oxygen deficiency in sediments leads to dissolution of hydrated manganese oxide, followed by dissolution of iron oxide. In this divalent state, these ions are soluble, as well as any co-precipitates with metallic coatings. Forstner and Prosi (1979) found indications that Cu, Zn, and Cd are released from anoxic sediments into surface waters.

Grand Lake exhibits a dimictic type of thermal stratification (Sorenson 1989). During the summer stratification period, the hypolimnion becomes anoxic and the pH is reduced to about 6.0 - 7.0, producing a potential for considerable redissolution of toxic metals from the sediments and later redistribution throughout the lake.

Due to the hardness of the water in Grand Lake and the resulting rapid sedimentation, the system appears to serve as an effective sink for heavy metals. Most of the toxic metals are not very soluble and therefore quickly adsorb onto particulate matter in the impacted ecosystem. As a result of the rapid sedimentation rate in Grand Lake, the water column metal levels rapidly decrease, even close to the source of input. However, intermittent resuspension of the sediments occurs due to flooding of the Neosho and Spring Rivers which can produce currents for several miles downstream into the lake and result in sediment redistribution (Benoit el al. 1969).

Factors such as these contribute to the problem of determining heavy metal bioavailability in aquatic systems. Since most aquatic organisms are in contact with trace metals in dissolved and particulate forms, accumulation can occur from the water or the solid phases (Tessier and Campbell 1987). Thus, the particulate fraction may serve as a significant chronic and acute source of metals to biota. The feeding habits of detritivores and possible physical disturbances such as dredging or seasonal flooding, respectively, account for these potential responses.

In an extensive review on the effects of heavy metal contamination on aquatic organisms, Mance (1987) found several trends. First, it was observed that salmonid species are ten times more sensitive to the effects of cadmium than are the non-salmonids. This trend was repeated for the short-term (4-day exposure) effects of zinc, but was contradicted for long-term exposure. Here, non-salmonids were found to be at least as sensitive to the effects of zinc as the salmonids. Mance found little difference in the response of salmonids and non-salmonids to the effects of lead. Also, there appears to be no difference in the toxicity of the various inorganic salts of lead.

Mance (1987) found that for all fish species, as water hardness (mg/l as CaCO3) increases, toxicity decreases. He also found that the adverse effect level decreases with an increase in the duration of lead and cadmium exposure.

> In an assessment of effects on invertebrates, Mance found that crustaceans were most sensitive to lead and cadmium. This class was most commonly represented by D. magna, with little to no information concerning C. dubia. It was found that insect larvae were the least sensitive to the effects of cadmium, with response concentrations corresponding to those of freshwater fish. Studies of the effects of water hardness using Tubifex and D. magna show that an increase in hardness reduced zinc toxicity, but other studies were inconclusive, or in some cases, even suggested the reverse.

Variability among reported effects levels is high for most metals. O'Donnell et al. (1985) found a range from 0.01 - 63,500 ug/l in a review of

101 studies of copper toxicity in aquatic systems. Biological, chemical and experimental factors contribute to this variation.

In preparation for an assessment of the acute toxicity of contaminated sediments, Ziegenfuss et al. [16] found D. magna to be more sensitive than Chironomus tentans in seventeen standard acute toxicity tests of organic chemicals and heavy metals without sediment, significantly so for heavy metals. In a sediment toxicity test using both D. magna and C. tentans, the 48-hour LC50's for kepone were calculated for each species based on the chemical concentration in the sediment, the column water and the sediment interstitial water. The results indicated that the primary exposure was via the water, not the sediments as such. This conclusion was based on the fact that the LC50 values of the water concentrations were about equal with and without sediments (Ziegenfuss et al. 1986).

Adams et al. (1985) examined the effects of kepone-contaminated sediment on C. tentans. The study concluded that the main route of exposure was from the interstitial water and or the water at the sediment-water interface.

Geisy et al. (1988) compared three sediment bioassay techniques using sediments from the Detroit River contaminated with heavy metals and organic compounds. The ability of the D. magna 48-hour lethality assay, the Photo bacterium phosphoreum 15-minute bioluminescence inhibition (Microtox) assay and the C. tentans 10-d growth reduction assay to distinguish grades of toxicity was assessed. Of the three, the first two were conducted with sediment pore water and the latter with whole sediment samples.

It was found that the D. magna 48-h acute bioassay was capable of predicting toxicity so great that benthic invertebrates would not be expected to be present. The Microtox assay was found to be the most sensitive and the D.magna assay the least sensitive in distinguishing between grades of sediment toxicity. However, based on lethality, the C. tentans assay was less sensitive than the D. magna assay. Correlations between the results of all the assays existed, but the results of one assay did not accurately predict the results of the other two.

Bioavailability can best be described using a physiological response of an organism, in this case, sequestering of heavy metals in tissues. Possible tissues to consider include liver, bile duct and gall bladder; previous work found little value in muscle tissue as an indicator (Aggus et al. 1982). This study also found cadmium, chromium, lead and zinc in the livers of omnivorous and piscivorous fish. At that time no data were available for planktivorous fish.

Similar results were found in a study of metal-contaminated lakes in the Sudbury region of northeast Ontario. Analyses of fish tissues revealed that muscle was a poor indicator of increased metal availability. Liver tissue proved to be a good indicator for copper, and kidney tissue for nickel (Bradley and Morris 1986).

It has been demonstrated that uptake via the gills is a primary mechanism for the water-soluble fraction of metal contaminants (Part and Svanberg 1981) and (Thomas et al. 1983). In heavily polluted aquatic systems with elevated contamination of particles and prey organisms, metal uptake by the intestinal lumen may be of primary importance. Dallinger and Kautzky (1985) found evidence that the uptake of heavy metals through a short food chain by rainbow trout, Salmo gairdneri, can be an important factor in the heavy metal budget of the fish.

Theoretically, the main routes of exposure of fish to cadmium would occur through the food, water, or a combination of both. However, Hatakeyama and Yasuno (1982) demonstrated with a combined feeding and exposure to water levels study, that for cadmium, the principal route appears to be via the water. Williams and Giesy (1978) found no significant increase in whole-fish cadmium levels in control water regardless of food concentration, whereas fish subjected to 10 ug/l in the water had significantly higher cadmium residues than the control. That the gills are the primary site of uptake is supported by several studies (Part and Svanberg 1981) and (Kumada et al. 1980). Accumulation of cadmium within specific tissues once uptake occurs has also been well documented (Benoit et al. 1976; Eaton 1974; Edgren and Notter 1980; and Sangaland and Freeman 1979). These authors found that cadmium was principally distributed in the kidney, liver and gills.

Excretion of heavy metals in vertebrates occurs mainly through renal and biliary pathways. Factors affecting excretion of heavy metals include chelating agents, synergistic effects, fluctuations in acid-base equilibria, nutritive status, parasite load, or otherwise poor environmental conditions. Since these same factors affect the excretion of essential metals, any change in homeostasis may indicate concentration changes in these metals as well.

A study by Grahl et al. (1985) on the excretion of heavy metals by fish, tested the utility of fish bile as an indicator of environmental toxicants and for identification of chronic heavy metal intoxication. These heavy metal complexes usually occur as low-molecular weight compounds while higher molecular weight compounds such as metallothioneines are filtered by glomeruli but then undergo reabsorption. Gel-permeation studies find evidence of higher-molecular weight compounds in the bile.

Although analysis for the presence of metallothionein has been suggested by Roch et al. (1986) as an alternative indicator of heavy metals, other data show that in the natural environment, two low-molecular weight non-metallothionein proteins are involved in the detoxification of cadmium. A study by Thomas et al. (1983) found that at relatively low levels of cadmium such as in natural waters, two proteins in the liver and kidney were active in sequestering the cadmium while metallothioneins in the liver were not activated except at very high levels, ie. 1000 ug/ml.

Because of difficulties described previously there can be no universally accepted scale for monitoring contamination by metal residues in fish. Applications on a local scale and in particular, in long-range studies, seem more appropriate.

Given the preceding observations, analyses of tissues such as liver, kidney, and gill of fish seems to be the most appropriate monitor for the presence of low-level chronic metal contaminants. To estimate the bioavailability of these contaminants in Grand Lake, metal levels in 3 tissues of fish collected from the lower end will be compared with those from the upper end of the lake. Gizzard shad, Dorosoma cepedianum are relatively territorial and thus, spend a majority of their life cycle in a relatively small area of the lake. Shad are filter-feeders, straining detritus from the bottom and plankton from the water. Analysis of liver and kidney tissue will provide a means of estimating recent exposure.

Since a similar, previous study (Aggus et al. 1982) was done in 1982, further research based on the same parameters should provide some insight into the long-term effects of heavy metals loading on the fish of this aquatic system. Also, background data have been accumulated on the metal concentrations at different depths of Grand Lake since that period.

Most criteria for assessing the aquatic environment have been based on aqueous concentrations in the water column. However, sediment quality may also affect aquatic life and criteria have recently been developed to assess these effects.

One approach involves the concept of the sediment quality triad developed by Chapman which incorporates in situ studies, sediment bioassays, and sediment chemistry (Chapman 1986). When applied to the present study, incorporation of in situ bioaccumulation levels with results of laboratory bioassays on natural sediments, and results of sediment chemical analysis should provide an estimate of whether or not the metals in Grand Lake sediments are detrimentally bioavailable.

DESCRIPTION OF SAMPLING LOCATIONS:

Water and sediment samples

Water and sediment samples were collected from four previously established sampling stations selected by the Grand River Dam Authority.

GRDA #1 was located approximately 40 miles upstream from the Pensacola Dam and approximately 2.5 miles down stream of the confluence of the Spring and Neosho Rivers. Maximum depth was 45 feet and the shoreline was steep with abundant vegetation.

GRDA #2 was located underneath Sailboat Bridge, approximately 23.5 miles upstream of the Pensacola Dam. Maximum depth was 70 feet and the shoreline was relatively flat with plentiful vegetation.

GRDA #3 was located near Two Tree Island, approximately 11.5 miles upstream from the Pensacola Dam. Maximum depth was 112 feet. The shoreline was extensively developed with residential areas just above the flood plain.

GRDA #4 was located approximately 1 mile upstream of the Pensacola Dam with a maximum depth of 112 feet.

Fish collection sites

Fish were collected from stations 1 and 4 to compare heavy metal residue levels at the outermost areas in the lake.

MATERIALS AND METHODS:

Metals Analysis

Sample handling - All glass and plastic ware used in collection and analysis of water, sediment and fish tissue samples was washed with detergent and rinsed with acid and double- distilled water. Fish samples were dissected as soon as possible after capture and were frozen when circumstances did not permit immediate dissection. Sediment samples were stored at 4 degrees Celsius.

Quality control

In the spectrophotometric analysis for heavy metals of water, sediment and fish tissues, a duplication rate of at least 20% was maintained. Standard practice included analysis of field blanks (for water sample analysis), procedural blanks and EPA quality control reference solutions, including analysis of freeze-dried fish reference tissues.

Water and sediment collection and analysis

Variables measured in the field included turbidity, Secchi disk transparency, conductivity, pH, temperature and dissolved oxygen. Measurements were made with a Hydro-lab Digital 4041, Yellow Springs Instrument dissolved oxygen field meter and turbidity was measured with a Hach@ turbidimeter. Water samples were collected with an acrylic Van Dorn water sampler for measurement of the following metals: arsenic, cadmium, copper, mercury, lead, iron, zinc and selenium. Samples were filtered through a 0.45 um membrane for analysis of dissolved and suspended metal content. The analyses were performed with a Perkin Elmer Model 5000 Atomic Absorption Spectrophotometer equipped for both flame and graphite furnace analysis. Water samples were collected once a month for four months and sediment samples were collected twice during the same period. Methods for metals analysis were taken from USEPA Methods for the Chemical Analysis of Water and Wastes (EPA 1979).

Fish collection and analysis

Gizzard shad were collected by personnel of the Oklahoma State University Cooperative Fish and Wildlife Unit via electroshock and gill netting from GRDA #4 from mid-April to mid-May. Fish from GRDA #1 and #2 were collected by throw net in mid-September by a local fisherman.

All analyses of liver and kidney tissue were per formed via atomic absorption spectrophotometry after acid digestion. Individual organs were weighed to 5 decimal places on a Mettler H20T analytical balance. Tissues and sediment were digested according to USEPA's Method 3050 (EPA 1982) and can be summarized as follows: A homogeneous 0.1 - 2.0 g sample (wet weight) was digested with concentrated nitric acid and hydrogen peroxide. The digestate was refluxed with nitric acid and diluted to the appropriate volume with 0.2 N nitric acid (depending on the original tissue weight.)

Necessary reagents included double distilled water, reagent grade concentrated nitric acid and 30% hydrogen peroxide.

Sediment Extract Bioassays

Sample collection - Sediment samples were collected with an Ekman dredge at the four main stations described previously, GRDA #'s 1 - 4. Several grabs were made along a transect at each location and a composite prepared on site in polyethylene buckets. The composite sediment samples were stored in polyethylene bottles and iced immediately. Aliquots were taken for metals analysis and extract preparation.

Laboratory Control. - For each assay, a laboratory control of Hard Reconstituted Water (recon) was tested concurrently. Recon was prepared by adding measured amounts of NaHCO3, $CaSO_4$.H2O, MgSO4, and KCl to deionized distilled water in accordance with USEPA procedures [34]. Hard Recon has a pH about 7.6 - 8.0, an alkalinity of 110 - 120 and a hardness of about 160 - 180, both measured as mg/l of CaCO3.

Extract preparation - Sediment extracts were prepared to investigate potential effects upon two species of daphnids, one species of amphipod and fathead minnow embryos. A measured portion of the sediment was treated at pH 4, 8 and 10 and tumbled for 24 hours in either Grand Lake column water from the appropriate station or reconstituted water of the appropriate hardness. The extracts were contained in polyethylene bottles and tumbled in a Rotatox tumbling unit. A 1:4 sediment to water ratio was maintained for all extract preparation. At 1, 4, 12 and 23 hours, the pH was monitored and readjusted if necessary. At the end of the 24- hour period, the pH for all samples was adjusted to pH 8 and either centrifuged for 15 minutes at 10,000 rpm or allowed to settle overnight before introduction of the test organisms.

7-Day Ceriodaphnia dubia Survival and Reproduction Test - This assay was performed according to USEPA's Method 1002.0 (EPA 1989). Less than 24-hour old neonates were used. Endpoints compared were survival and reproduction. Test water was renewed daily and neonates counted and removed. Mean total numbers of young produced at the end of the 7-d 3-brood period were compared. See Table 47 for a summary of test conditions. Grand Lake column water samples collected approximately half a meter below the surface of stations 1 - 4 were tested.

Table 47. Conditions for 7-day *Ceriodaphnia dubia* survival and reproduction assay.

1.	Test type:	static renewal
2.	Temperature:	26.0 + 1.0 °C
3.	Light quality:	ambient laboratory illumination
4.	Light intensity:	10 - 20 uE/m2/s
5.	Photoperiod:	16 h light, 8 h dark
6.	Test chamber size:	30 ml
7.	Test solution volume:	15 ml
8.	Renewal of test: solutions:	daily
9.	Age of test organisms:	<24 h, and released within an 8-h period
10.	No. neonates per chamber:	1
11.	No. replicate test chambers:	10
12.	Feeding regime:	fed 0.1 ml each of TCY and algal suspension daily
13.	Aeration:	none
14.	Control Water:	Hard Reconstituted Water
15.	Samples tested:	Grand Lake column water from four stations collected approximately half a meter below the surface

96-hour D. magna Survival Assay - After the 24-hour tumbling period, sediment extracts were adjusted to pH 8 and a 500-ml aliquot of each extract poured into 4 250-ml polycarbonate centrifuge bottles and centrifuged for 15 minutes at 10,000 rpm. Three of the bottles containing 100 ml each were used as replicates in a 96-h D. magna toxicity test. Eight juvenile D. magna were used per replicate. The organisms were fed one drop of TCY digest per bottle on Days 0 and 2 of the test. At the end of the 96-h period, the overlying water was filtered through a fine mesh screen and the organisms recovered and counted.

The overlying water, about 200 ml, in the remaining centrifuge tube was used in a teratogenicity assay, monitored for physical-chemical parameters and a 100-ml aliquot filtered for suspended and dissolved metal levels. At the end of the 96-hour test period, overlying water from the three replicates was combined for measurement of physical-chemical parameters.

H. azteca 48-Hour Assay and C. dubia 48-Hour Assay - In these assays, only sediment extracts from stations 1 and 4 were tested. Grand Lake column water was used in a 1:4 sediment to water ratio. The mixture was tumbled as before and all extracts adjusted to pH 8 at the end of the 24-hour tumbling period.

Fifteen ml of the extract were poured into 30-ml plastic containers for the C. dubia assay and 10 ml per plastic petri dish for the H. azteca assay. The extracts were allowed to settle overnight before introduction of the test organisms. Less than 24-hour old C. dubia neonates and 1-2 week old H. azteca juveniles were used.

Lack of clarity in the extracts tumbled at pH 8 and 10 prevented an accurate count on Day 1 of the test. Upon termination of the test, the extract was poured through a fine mesh screen to recover the organisms.

Fathead Minnow 7-day Embryo-Larval Survival and Teratogenicity Assay - This assay was performed according to USEPA's Method 1001.0 (EPA 1989). Fathead minnow embryos were exposed to sediment extracts from four lake stations for seven days in a static renewable test. On days 2, 4 and 6, the water was renewed. Once a day, the test chambers were cleaned by removal of dead organisms and egg cases from recently hatched larvae. Only those organisms with gross physical deformities such as lack of appendages, lack of fusiform shape, lack of mobility or other survival-limiting characteristics were considered abnormal and counted as dead. Endpoints compared in this test included total percent mortality, combined number of dead embryos and dead and deformed larvae. See Table 48 for conditions employed in this assay.

Statistical Analyses

All statistical analyses were performed with the aid of TOXSTAT, a statistical software package (Gulley et al. 1989). Shapiro-Wilks Test ($p=0.01$) and Bartlett's Test were used to test for normality and homogeneity of variance, respectively. All percent survival or percent mortality data were transformed (arc-sine) before analysis.

Reproduction data for the 7-day C. dubia assay were compared with a non-parametric method, Steel's Many-One Rank Test ($a=0.05$). All other comparisons were made with Tukey's Test or Mean Comparison ($p=0.05$).

Table 48. Conditions for the fathead minnow (*Pimephales promelas*) embryo-larval survival and teratogenecity test.

1.	Test type:	static renewal
2.	Temperature:	26.0 + 1.0 °C
3.	Light quality:	ambient laboratory illumination
4.	Light intensity:	10 - 20 uE/m2/s
5.	Photoperiod:	16 h light, 8 h dark
6.	Test chamber size:	25 ml
7.	Test solution volume:	8 ml
8.	Renewal of test: solutions:	every other day
9.	Age of test organisms:	<36 h
10.	No. embryos per chamber:	8
11.	No. replicate test chambers:	3
12.	No. embryos per sample:	24
13.	Feeding regime:	none required
14.	Aeration:	aerated for 30 minutes before initiation of test
15.	Control Water:	Hard Reconstituted Water
16.	Samples tested:	sediment from four stations extracted at pH 4, 8, and 10

RESULTS AND DISCUSSION:

Bioassays

7-day C. dubia Survival and Reproduction Assay - Ten replicates per sample of column water were used. The average number of young produced at the end of 7 days was 21.5 for the control and ranged from 19.5 to 24.6 for the four samples tested. No significant difference in survival or reproduction was detected when the control was compared against lake samples (Table 49).

Table 49. Survival and Reproduction of *C. dubia* Exposed to Grand Lake Water Column Samples.

Sample Station	Total Tested	Number Surviving	Mean No. of Young	SD
Hard Recon	10	10	21.5	1.96
1 Surface	10	10	19.5	2.64
2 Surface	10	9	23.3	3.74
3 Surface	10	9	24.6	4.81
4 Surface	10	10	20.1	7.70

48-h C. dubia and H. azteca Assay - Ten replicates per sample for C. dubia and 3 replicates per sample for H. azteca were employed in these assays. Samples tested included a control of untreated hard recon and hard recon and sediment from stations 1 and 4 extracted at ph 4, 8 and 10. Since the extracts were prepared with Grand Lake column water, blanks consisting of column water from stations 1 and 4 were also tested. Fisher's Exact Test [35] showed no significant difference when compared to the control.

96-h D. magna Survival Assay - Percent survival data for three replicates of eight organisms each were averaged and compared using Tukey's Method of Multiple Comparisons after arc-sine transformation (Gulley et al. 1989). When extracts from sediment from stations 2 and 3 were compared, no significant difference was found. When extracts from stations 1 and 4 were compared, sediment from station 4 extracted at pH 4 produced a mean of 83 percent mortality and was significantly different from the control and all other groups. Survival for the laboratory control was 96 percent and ranged from 91.7 - 75.3 percent for the recon blanks (Table 50).

7-d Fathead Minnow Survival and Teratogenicity Assay - Three replicates of eight embryos each were used per sample. Tukey's Method yielded no significant differences between groups when recon and sediment from station 1 and 4 were compared [35]. When the control and sediment from stations 2 and 3 were compared, mean transformed percent mortality for station 3 sediment treated at pH 10 was significantly greater than percent mortality in the control. However, this observed mortality was probably due to fungal growth in the three replicate test chambers. Fungal growth did not occur in any other extracts or control groups. When compared solely on the basis of pH, mean percent mortality for station 4 sediment at pH 8 was significantly greater than percent mortality in the control (Table 51). High levels of dissolved cadmium and lead in both groups may be responsible for some toxicity (Table 54 & Table 55).

Table 50. 96h Survival of ***Daphnia magna*** to Extracts of Grand Lake Sediment.

Sample	pH	Fraction Survivial Mean Transformed	Mean Original	Significance
Hard Recon	I	1.334	0.960	
Hard Recon	4	1.160	.0837	
Hard Recon	8	1.278	0.917	
Hard Recon	10	1.060	0.753	
Station 1	4	1.278	0.917	
Station 1	8	1.393	1.000	
Station 1	10	1.278	0.917	
Station 2	4	1.334	0.960	
Station 2	8	1.393	1.000	
Station 2	10	1.393	1.000	
Station 3	4	1.393	1.000	
Station 3	8	1.278	0.917	
Station 3	10	1.334	0.960	
Station 4	4	0.420	0.170	*
Station 4	8	1.393	1.000	
Station 4	10	1.393	1.000	

a Laboratory control
* Significant at $p = 0.05$

Table 51. Teratogenecity and Survival of Fathead Minnow Embryo-Larvae to Grand Lake Sediment Extracts.

		Fraction Mortality		
Sample	pH	Mean Transformed	Mean Original	Significance
aH. Recon	I	0.178	0.000	
H. Recon	4	0.420	0.170	
Station 1	4	0.357	0.127	
Station 2	4	0.472	0.210	
Station 3	4	0.241	0.043	
Station 4	4	0.408	0.337	
aH. Recon	I	0.178	0.000	
H. Recon	8	0.178	0.000	
Station 1	8	0.357	0.127	
Station 2	8	0.420	0.170	
Station 3	8	0.455	0.210	
Station 4	8	0.587	0.310	*
aH. Recon	I	0.178	0.000	
H. Recon	10	0.241	0.043	
Station 1	10	0.241	0.043	
Station 2	10	0.559	0.293	
Station 3	10	0.637	0.363	
Station 4	10	0.603	0.337	

a = Laboratory control
* Significant at p=0.05
b = Fungal infection

Table 52. Summary of Toxic Responses to Grand Lake Sediment and Water Column Samples.

Organism Tested	Length of Exposure	Samples Tested	Endpoints	[a]Significant Toxicity
C. dubia	7-days	Grand L. column, 1 - 4	Survival, Reproduction	none
C. dubia, H. azteca	48-hours	Sediment Extract, 1 and 4	Survival	none
D. magna	96-hours	Sediment Extract, 1 and 4	Survival	4 (4)
P. promelas	7-days	Sediment Extract, 1 and 4	Survival, Teratogenicity	[b]3 (10) 4 (8)

a = Significant at p=0.05
b = fungal growth

Metal Levels

Values from the USEPA Quality Criteria for Water, 1986 (Table 53) were used in the comparisons of sediment extract and column water levels [36]. Values for the protection of freshwater organisms are applicable to waters with 100 mg/l hardness measured as $CaCO_3$.

Table 53. Summary of EPA National Water Quality Criteria for Metals (EPA 1986).

Element	Ambient Water Quality	[a]Protection of Freshwater Organisms
As	"0"	190 ug/l
Cd	10 ug/l	1.1 ug/l
Cu	1 mg/l	12 ug/l
Fe	0.3 mg/l	1.0 mg/l
Pb	50 ug/l	3.2 ug/l
Se	10 ug/l	35 ug/l
Zn	5 mg/l	320 ug/l

a = at 100 mg/l hardness

Sediment Extracts

Results of metals analyses of sediment extracts show some levels greater than the criterion set forth by the USEPA for the protection of aquatic life. Levels of suspended lead in the set of extracts used in the 48-h C. dubia and H. azteca assays exceed the criterion of 3.2 ug/l. Other metals in excess of the USEPA limits include dissolved cadmium and zinc and suspended zinc, iron and copper (Table 54 & Table 55) [36]. Levels of dissolved metals which exceed USEPA criteria appear to occur more frequently in sediment extracted at pH values of 8 and 10, regardless of location of station on the lake (Table 56 & Table 57).

Table 54. Concentration of Zinc, Cadmium and Lead in Grand Lake Sediment Extracts Used for Toxicity Tests.

Element	Zn		Cd		Pb	
Units	mg/l		ug/l		ug/l	
[a]Station/Sample (pH)	Susp.	Diss.	Susp.	Diss.	Susp.	Diss.
Recon (unt.)	0.036	0.013	<0.10	<0.10	<1.50	<1.50
Recon (4)	0.021	0.052	<0.10	0.20	[b]4.86	1.76
Recon (8)	0.013	0.023	<0.10	<0.10	1.87	<1.50
Recon (10)	0.014	0.013	<0.10	0.12	<1.50	<1.50
1 W (4)	0.024	0.023	0.21	0.11	[b]6.23	<1.50
1 W (8)	0.029	0.015	<0.10	<0.10	<1.50	<1.50
1 W (10)	0.063	0.013	<0.10	<0.10	<1.50	<1.50
4 W (4)	0.142	0.066	<0.10	0.15	[b]6.03	3.05
4 W (8)	0.075	0.041	<0.10	0.29	1.61	<1.50
4 W (10)	0.025	0.052	0.11	0.39	<1.50	<1.50
1 S (4)	0.104	[b]0.409	0.17	0.35	[b]3.87	<1.50
1 S (8)	0.254	0.010	0.37	1.10	[b]7.75	<1.50
4 S (4)	0.239	0.142	0.25	[b]1.17	[b]8.38	<1.50
4 S (8)	[b]0.659	0.018	0.66	<0.10	[b]36.07	<1.50

[a]W = column water
S = sediment
[b]Exceed USEPA criteria (Table 7)

Table 55. Iron and Copper Concentration in Grand Lake Sediment and Water Samples Tested for Toxicity.

Element	Fe		Cu	
Units	mg/l		ug/l	
[a]Station/Sample (pH)	Susp.	Diss.	Susp.	Diss.
Recon (unt.)	<0.06	<0.06	1.88	3.56
Recon (4)	<0.06	<0.06	2.20	3.06
Recon (8)	<0.06	<0.06	2.78	3.34
Recon (10)	<0.06	<0.06	1.52	2.29
1 W (4)	0.16	<0.06	2.32	4.56
1 W (8)	<0.06	<0.06	1.93	4.52
1 W (10)	0.14	<0.06	2.32	3.74
4 W (4)	<0.06	<0.06	2.50	4.71
4 W (8)	0.10	<0.06	3.01	4.91
4 W (10)	<0.06	<0.06	2.95	4.93
1 S (4)	0.78	<0.06	5.19	1.14
1 S (8)	*b*6.58	<0.06	6.79	1.74
4 S (4)	*b*4.29	<0.06	6.92	6.55
4 S (8)	*b*27.82	0.27	*b*22.53	6.75

*a*W = column water
S = sediment
b = Exceed USEPA criteria (Table 7)

Table 56. Iron and Copper Concentration in Grand Lake Sediment and Water Samples Used in *D. magna* and Fathead Minnow Assays.

Element	Fe		Cu	
Units	mg/l		ug/l	
Station/Sample (pH)	Susp.	Diss.	Susp.	Diss.
Recon (unt.)	<0.06	<0.06	6.94	8.13
Recon (4)	<0.06	<0.06	[d]21.59	3.18
Recon (8)	<0.06	<0.06	5.78	2.18
Recon (10)	<0.06	<0.06	4.10	2.82
1 S (4)	[d]3.34	<0.06	6.30	2.89
1 S (8)	[d]21.89	0.16	[d]16.01	8.03
1 S (10)	[d]19.95	0.21	8.50	[d]36.86
2 S (4)	[d]5.48	<0.06	4.12	3.26
2 S (8)	[d]20.33	0.21	[d]16.31	8.95
2 S (10)	[d]100.90	[d]6.50	[d]23.94	[d]42.27
3 S (4)	[d]3.24	<0.06	2.36	4.83
3 S (8)	[d]37.9	0.60	8.26	[d]13.29
[a]3 S (10)	[d]59.7	[d]53.3	[d]22.96	[d]102.0
[b]4 S (4)	[d]2.18	<0.06	4.82	2.43
[c]4 S (8)	[d]33.3	[d]7.81	10.32	[d]43.03
4 S (10)	[d]71.0	0.64	[d]36.53	[d]20.95

[a],[c] = Significant mortality to fathead minnow embryos
[b] = Significant mortality to D. magna
[d] = Exceed USEPA criteria (Table 7)

Hardness measured as mg/l $CaCO_3$ increased in the sediment extracts treated at pH 4, possible mediating toxicity due to high levels of dissolved metals (Table 58 & Table 59).

Table 57. Physical-Chemical Properties of Sediment Extracts Used in *C. dubia* and *H. azteca* assays.

Sample (pH)	Alkalinity	Hardness	Conductivity	pH	Dissolved Oxygen	Temp.
	mg/l as $CaCO_3$		uohms/cm	S.U.	mg/l	°C
R. (unt.)	114	142	490	8.2	8.2	26.2
R. (4)	42	154	650	7.8	7.9	26.2
R. (8)	118	150	500	8.2	7.8	26.2
R. (10)	114	108	605	8.2	7.8	26.2
1 W (4)	14	114	495	7.3	7.8	26.2
1 W (8)	80	110	390	8.0	7.9	26.2
1 W(10)	76	106	340	8.0	7.8	26.2
4 W (4)	20	116	405	7.5	8.0	26.2
4 W (8)	72	118	380	8.0	7.9	26.2
4 W (10)	62	60	350	8.0	7.9	26.2
1 S (4)	116	620	2500	7.1	7.4	26.2
1 S (8)	80	160	800	8.1	7.2	26.2
1 S (10)	166	160	560	7.8	5.0	26.2
4 S (4)	84	840	2200	7.5	7.2	26.2
4 S (8)	154	200	500	7.4	4.2	26.2
4 S (10)	336	200	800	7.8	1.0	26.2

Table 58. Physical-Chemical Properties of Sediment Extracts Used in the *D. magna* and Fathead Minnow Assays.

Sample (pH)	Alkalinity	Hardness	Conductivity	pH	Dissolved Oxygen	Temp.
	mg/l as $CaCO_3$		uohms/cm	S.U.	mg/l	°C
R. (unt.)	96	140	499	8.4	8.0	24.9
R. (4)	34	130	800	7.8	8.2	24.9
R. (8)	96	134	600	8.4	8.0	24.9
R. (10)	98	100	620	8.5	8.2	24.9
1 S (4)	16	650	2200	7.5	8.0	24.9
1 S (8)	--	108	620	8.1	8.0	24.9
1 S(10)	192	110	1510	8.4	7.8	24.9
2 S (4)	74	1300	4150	7.8	7.9	24.9
2 S (8)	136	90	1000	8.2	7.6	24.9
2 S (10)	148	120	1350	8.1	9.0	24.9
3 S (4)	152	1250	3600	8.1	8.0	24.9
3 S (8)	156	80	600	8.1	8.5	24.9
3 S (10)	124	110	2000	7.8	11.7	24.9
4 S (4)	158	1340	3500	7.5	5.5	24.9
4 S (8)	152	100	600	8.5	6.5	24.9
4 S (10)	148	80	1450	8.3	8.9	24.9

Significantly greater quantities of dissolved metals were leachable from sediments extracted at the higher pH values of 8 and 10, even though the total quantities of metals in the lower portion of the lake are less than in the upper end. This may be due more to the chemical form or species than actual amount present. DiToro (1989) has recently hypothesized that the quantity of iron sulfide in sediments may be controlling availability of trace metals. Since most toxic metals form insoluble metallic sulfide salts in the presence of ferrous sulfide, high levels of sulfides would prohibit solubilization of toxic metals from sediments into the overlying water column until all the sulfides had either reacted with more electronegative elements or oxidized to sulfates. Since anoxic conditions were observed for bottom water and sediments, most metals would probably remain bound (Appendix - Field Data).

The sediments in the upper end of Grand Lake appear to be strongly reduced, ie., dark brown to black in color with a strong sulfide odor. This condition may result in a stronger sequestering of the toxic metals as insoluble sulfide salts and thus reduce transport throughout the lower portion of Grand Lake. Obviously, some metals are transported to the lower portion of the lake as evidenced by D. magna bioassay results, however, the physical-chemical conditions in the upper end of lake are acting as a sediment trap to greatly reduce the total quantity transported.

Column Water

Levels of suspended metals in excess of USEPA criteria occurred most frequently for station 1, below the confluence of the Spring and Neosho Rivers and gradually decreased at the lower stations (Table 60 - Table 63). Levels of dissolved metals were lower overall than suspended, and again, gradually decreased toward the lower portion of the lake.

Table 59. Concentration of Suspended Metals from Grand Lake Stations 1 and 2 Water Column Samples.

Date	6-89		7-89		8-89		10-89	
[a]Depth	S	B	[b]S	[b]B	S	B	S	B
Element								
				Station 1				
Fe, mg/l	1.5	[c]2.9	[c]3.6	[c]4.4	[c]1.0	[c]3.1	0.6	0.7
Cd, ug/l	0.2	0.5	<0.1	<0.1	<0.1	0.1	0.2	0.2
Pb, ug/l	<1.0	3.1	[c]7.5	[c]4.5	[c]2.7	[c]6.0	<1.0	1.9
Zn, mg/l	0.0	0.1	0.2	0.1	0.1	0.1	0.0	[c]0.7
Cu, ug/l	3.0	4.7	5.2	3.4	5.4	9.5	2.1	2.5
As, ug/l	<1.5	3.1	5.4	4.7	4.8	4.5	<1.5	<1.5
Se, ug/l	7.3	4.6	5.7	5.6	4.6	7.0	9.1	11.2
				Station 2				
Fe, mg/l	0.6	[c]1.3	0.5	[c]2.9	0.2	[c]3.2	0.4	[c]4.3
Cd, ug/l	0.6	0.3	0.4	0.3	<0.1	<0.1	0.2	0.5
Pb, ug/l	<1.0	3.0	<1.0	[c]3.2	<1.0	2.1	2.0	[c]7.7
Zn, mg/l	0.03	0.10	0.16	0.08	0.05	0.09	0.05	0.12
Cu, ug/l	5.5	9.0	3.0	5.0	3.1	4.1	2.4	6.2
As, ug/l	3.3	4.0	5.0	4.2	4.6	4.0	<1.5	<1.5
Se, ug/l	4.2	5.1	5.0	5.0	6.0	5.1	4.2	14.0

[a]S = approximately half a meter below surface
B = approximately half a meter above bottom
[b] = mean of triplicate samples
[c] = Exceed USEPA criteria (Table 7)

Table 60. Concentration of suspended metals in Grand Lake stations 3 and 4 water column samples.

Date	6-89		7-89		8-89		10-89	
[a]Depth	S	B	[b]S	[b]B	S	B	S	B
Element								
				Station 3				
Fe, mg/l	0.17	0.46	0.27	0.83	0.07	0.28	0.25	0.24
Cd, ug/l	[c]1.83	0.64	<0.1	<0.1	<0.1	<0.1	0.63	0.28
Pb, ug/l	<1.0	[c]3.28	<1.0	<1.0	1.81	1.0	[c]5.13	[c]8.17
Zn, mg/l	0.05	0.30	<0.01	0.07	0.02	0.01	0.07	0.21
Cu, ug/l	7.59	7.41	1.85	2.36	2.58	3.63	4.24	1.08
As, ug/l	3.28	3.46	4.30	4.22	4.06	<1.5	<1.5	--
Se, ug/l	6.68	7.56	6.16	7.24	6.10	5.66	5.56	--
				Station 4				
[a]Depth	S	B	S	B	[b]S	[b]B	[b]S	[b]B
Fe, mg/l	<0.06	0.35	0.35	0.17	0.09	0.27	0.16	[c]1.11
Cd, ug/l	0.49	0.47	0.10	<0.10	<0.1	<0.1	0.42	0.28
Pb, ug/l	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.10
Zn, mg/l	0.07	0.03	0.03	0.09	0.03	0.03	0.04	0.08
Cu, ug/l	4.07	4.77	4.70	2.01	3.79	2.55	2.68	4.28
As, ug/l	3.64	3.70	4.26	4.12	<1.5	<1.5	<1.5	<1.5
Se, ug/l	7.74	7.18	5.32	5.36	<2.0	<2.0	6.90	6.74

[a]S = approximately half a meter below surface
B = approximately half a meter above bottom
[b] = mean of triplicate samples
[c] = Exceed USEPA criteria (Table 7)

Table 61. Concentration of dissolved metals in Grand Lake stations 1 and 2 water column samples.

Date	6-89		7-89		8-89		10-89	
[a]Depth	S	B	[b]S	[b]B	S	B	S	B
Element								
				Station 1				
Fe, mg/l	0.06	0.09	0.14	0.24	0.11	0.11	0.16	0.12
Cd, ug/l	[c]1.56	0.72	0.02	<0.1	<0.18	<0.1	<0.1	<0.1
Pb, ug/l	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	[c]26.03	[c]15.0
Zn, mg/l	0.02	0.06	0.02	0.03	0.05	0.07	0.09	0.10
Cu, ug/l	2.97	[c]13.09	5.85	5.00	3.27	3.14	[c]47.00	[c]40.0
As, ug/l	3.12	3.48	4.09	4.08	3.92	5.44	<1.5	<1.5
Se, ug/l	8.92	8.92	8.95	9.18	16.70	22.76	15.76	13.46
				Station 2				
[a]Depth	[b]S	[b]B	S	B	S	B	S	B
Fe, mg/l	0.07	0.13	0.02	<0.06	<0.06	<0.06	0.59	0.21
Cd, ug/l	0.20	0.60	<0.10	<0.10	<0.1	<0.1	0.18	0.14
Pb, ug/l	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	[c]12.43	1.88
Zn, mg/l	0.03	0.05	0.01	0.11	0.03	0.02	0.09	0.04
Cu, ug/l	3.56	4.77	3.94	1.03	2.64	3.85	24.47	5.22
As, ug/l	3.38	3.01	4.46	4.48	3.60	5.30	<1.5	<1.5
Se, ug/l	8.93	7.39	7.70	9.30	11.48	12.62	12.86	18.78

[a]S = approximately half a meter below surface
B = approximately half a meter above bottom
[b] = mean of triplicate samples
[c] = Exceed USEPA criteria (Table 7)

Table 62. Concentration of dissolved metals in Grand Lake stations 3 and 4 water column samples.

Date	6-89		7-89		8-89		10-89	
[a]Depth	S	B	[b]S	[b]B	S	B	S	B
Element								
				Station 3				
Fe, mg/l	0.32	<0.06	<0.06	0.87	<0.06	<0.06	0.10	<0.06
Cd, ug/l	0.47	0.25	0.10	<0.1	<0.10	<0.1	<0.1	<0.1
Pb, ug/l	<1.0	<1.0	<1.0	[c]3.62	<1.0	<1.0	1.48	<1.0
Zn, mg/l	0.05	0.03	0.01	0.08	0.02	0.05	0.04	0.01
Cu, ug/l	3.21	2.55	2.28	9.67	3.22	2.28	2.68	1.98
As, ug/l	4.48	3.92	4.54	4.64	<1.5	<1.5	<1.5	--
Se, ug/l	9.76	9.86	8.32	9.68	13.62	12.48	14.38	--
				Station 4				
[a]Depth	S	B	S	B	[b]S	[b]B	[b]S	B
Fe, mg/l	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	[c]1.03	0.24
Cd, ug/l	<0.10	0.30	<0.10	<0.10	<0.1	<0.1	<0.10	<0.1
Pb, ug/l	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Zn, mg/l	0.03	0.03	<0.01	0.02	0.09	0.06	0.10	0.05
Cu, ug/l	1.85	2.31	3.11	1.90	2.71	2.31	2.43	3.92
As, ug/l	3.86	3.68	4.26	4.36	<1.5	<1.5	<1.5	<1.5
Se, ug/l	6.30	10.02	7.32	8.12	13.77	14.85	11.35	6.74

[a]S = approximately half a meter below surface
B = approximately half a meter above bottom
[b] = mean of triplicate samples
[c] = Exceed USEPA criteria (Table 7)

Sediment

Sediment samples were collected twice for metals analysis. The number of replicates for the first sampling time was 8 for stations 1 and 2 and 7 for stations 3 and 4. For the second sampling time 2 replicates were used per station. Means were compared using the method of Least Squares Means at the 95 percent confidence level. All levels of metals in sediment are expressed as wet weights (Table 64). For cadmium, station 1 and 2 levels were significantly higher than station 4, and station 1 was also different from 3. For iron, levels in station 1 and 2 sediment were significantly higher than levels in station 3 and 4. Lead levels in sediment from station 1 were significantly higher than levels from stations 2, 3 and 4. For zinc, levels in station 1 sediment were higher than levels at stations 3 and 4. No significant differences in copper levels were found for sediment. Levels of iron, lead, zinc and cadmium in sediment from station 1 were lower than previous levels reported by McCormick for a similar area (McCormick 1985). None of the levels exceed the United States Geological Survey "Alert Levels" for sediments (USGS 1977).

Table 63. Concentration of metals in Grand Lake sediments.

Sample Station	N, total # of replicates	Mean	Standard Error	Element	[a]USGS "Alert Levels"
1	10	1356.6	112.3	Cadmium ug/kg	20,000
2	9	930.1	113.8		
3	10	577.2	112.3		
4	9	491.5	113.9		
1	10	11.3	0.54	Iron g/kg	-----
2	9	11.0	0.54		
3	10	7.8	0.54		
4	9	7.8	0.54		
1	10	16.1	0.97	Lead mg/kg	500
2	9	11.9	0.99		
3	10	9.1	0.97		
4	9	10.5	0.99		
1	10	322.2	23.11	Zinc mg/kg	5,000
2	9	257.9	23.44		
3	10	198.4	23.11		
4	9	208.5	23.44		
1	10	8472.2	795.0	Copper ug/kg	2,000
2	9	7153.5	806.3		
3	10	5097.9	795.0		
4	9	6174.9	806.3		

a United States Geological Survey

SUMMARY : Levels of metals in the sediments of the upper stations are higher than in the lower stations. This is demonstrated by both fish and water levels:

higher levels of zinc in shad from station 1 than station 4 and higher levels of suspended and dissolved metals in station 1 column water than station 4.

However, the only toxicity observed in any of the organisms tested occurred with sediment extracts from stations 3 and 4, indicating that the physical conditions of sediment from the upper stations are acting as a more effective trap for the metals. In general, levels of metals extracted at pH 10 are higher than those extracted at pH 4, independent of station location. This is probably due to sulfide chemistry. More metals will remain bound or in the non-ionic form at lower pH values, depending upon the amount of sulfides present.

Table 64. Concentration of metals in Grand Lake sediments.

Sample Station	N, total # replicates	Mean	Standard Error	Element	[a]USGS "Alert Levels"
1	10	1356.6	112.3	Cadmium	20,000
2	9	930.1	113.8	ug/kg	
3	10	577.2	112.3		
4	9	491.5	113.9		
1	10	11.3	0.54	Iron	------
2	9	11.0	0.54	g/kg	
3	10	7.8	0.54		
4	9	7.8	0.54		
1	10	16.1	0.97	Lead	500
2	9	11.9	0.99	mg/kg	
3	10	9.1	0.97		
4	9	10.5	0.99		
1	10	322.2	23.11	Zinc	5,000
2	9	257.9	23.44	mg/kg	
3	10	198.4	23.11		
4	9	208.5	23.44		
1	10	8472.2	795.0	Copper	2,000
2	9	7153.5	806.3	ug/kg	
3	10	5097.9	795.0		
4	9	6174.9	806.3		

a United States Geological Survey

SUMMARY : Levels of metals in the sediments of the upper stations are higher than in the lower stations. This is demonstrated by both fish and water levels: higher levels of zinc in shad from station 1 than station 4 and higher levels of suspended and dissolved metals in station 1 column water than station 4.

SUBTASK 11f: Algal Analyses

METHOD: Samples were collected from the same stations and times as SUBTASK 11d, but from the epilimnion or euphotic zone only. An index of primary productivity was obtained by analyzing samples for chlorophyll a. dominant genera of algae in thephytoplankton cell density (numbers of cells per milliliter), and cell volume. See TASK 12.

SUBTASK 11g: Fish Flesh Analyses

METHOD: Gizzard Shad were collected for analysis of trace metal accumulation (cadmium, lead, and zinc). The concentrations of trace metals in liver and kidney tissue used were used as indicators of potential bioconcentration of metal contaminants.

Levels of cadmium were measured for gizzard shad caught at three stations on the lake: 1, 2 and 4 (Table 65 and Table 66). Sample size was 6, 8 and 8, respectively. All levels of metals in tissue are expressed as wet weights. Mean levels of cadmium were determined and compared via Tukey's Method of Multiple Comparisons (Gilbert 1987). No significant difference in liver or kidney cadmium levels was found.

Average levels of lead in liver and kidney tissue were compared and no significant difference was found between fish caught from station 1 and those from station 4.

Average levels of zinc in livers from fish collected from station 1 were significantly higher than levels in fish collected at station 4, 93.39 and 22.76 mg/kg, respectively. Levels in station 2 fish livers were also significantly higher with an average value of 51.24 ug/kg. For kidney tissue, levels of zinc in fish collected from station 1 were significantly higher than levels of fish from station 4, with values of 262.25 and 77.63 mg/kg, respectively (Table 66).

Table 65. Concentration of metal residues in Grand Lake gizzard shad liver tissue.

Station	N # of Fish	Mean	SD	SEM	Element
1	6	0.54	0.45	0.18	Cadmium
2	8	0.23	0.12	0.04	mg/kg
4	8	0.52	0.38	0.13	
1	6	1.97	2.41	0.98	Lead mg/kg
2	8	1.04	0.60	0.21	
4	8	0.43	0.41	0.15	
1	6	[a]93.39	32.79	13.39	Zinc mg/kg
2	8	[a]51.24	21.27	7.52	
4	8	22.76	7.83	2.77	

[a] Significant at $p = 0.05$ level

Table 66. Concentration of metal residues in Grand Lake gizzard shad kidney tissue.

Station	N # of Fish	Mean	SD	SEM	Element
1	6	0.45	0.51	0.21	Cadmium
2	8	0.12	0.09	0.03	mg/kg
4	8	0.36	0.21	0.08	
1	6	7.44	9.27	3.78	Lead mg/kg
2	8	2.54	1.85	0.65	
4	8	0.79	1.00	0.35	
1	6	[a]262.25	177.28	72.37	Zinc mg/kg
2	8	176.38	51.63	18.26	
4	8	77.63	59.34	20.98	

[a] Significant at $p = 0.05$ level

Table 67. Quality assurance analysis of EPA reference fish tissue metal residues.

Element	[a]known conc. mg/kg	observed conc. mg/kg	95% Confidence Interval
Zinc	43.6	42.4	35.5 - 51.7
Cadmium	0.16	0.15	[b]MDL - 0.32
Copper	2.21	2.70	0.93 - 3.49
Lead	0.26	0.15	[b]MDL - 1.10

[a] = mean of four replicates
[b] = Minimum detectable limit

Levels of zinc are significantly higher in shad from the upper end of the lake compared to shad from the lower end. Whether or not these levels are high enough to hinder reproductive success, thus causing a change in the population structure, is difficult to determine. Migration of fish from the lower end of the lake would probably compensate for any temporary effect, making an assessment based upon density of standing crop measures of fish difficult.

TASK 12: BIOLOGICAL RESOURCES

ALGAE: The dominant genera of algae identified in the EPA national eutrophication survey could be used to indicate Grand Lake was in the mesotrophic to early eutrophic condition (Table 68) (EPA 1979).

Table 68. Summary of dominant genera of algae identified during EPA national eutrophication survey (EPA 1977).

Taxa	Percent of Total Numbers			
	Date 4/2/74	Date 6/14/74	Date 8/29/74	Date 10/21/74
Ankistrodesmus falcatus	x		4.4	3.5
V. mirabilis		2.0		x
Aphanizomenon		x		
centric diatom	23.8	1.3		
Chlamydomonas		6.6	1.3	
Chlorogonium			1.3	
Chroomonas acuta	26.1	2.6	7.5	21.0
Crucigenia tetrapedia		2.6		
Cryptomonas sp	7.2	2.6		
Cryptomonas erosa			1.9	3.5
Cryptomonas keploxa			0.6	x
Cyclotella meneghiniaha			x	3.5
Dictyosphaerium pulchellum		0.7		x
Euglena sp.	4.8	x	1.9	
flagellate #2				14.1
Golehrinia radiata				3.5
Melosira distans	14.3	2.6	14.5	28
Melosira granulata	4.8	25.7	6.3	7.0

Table 68. Continued.

Taxa	Percent of Total Numbers			
	Date 4/2/74	Date 6/14/74	Date 8/29/74	Date 10/21/74
V. argustissira		1.3	x	3.5
Merismopedia minima				1.8
Mesostigra viridis		x	1.3	3.5
Micractinium	9.5			
Microcystis incerta		0.7	1.9	x
Nitzschia		3.3	3.1	3.5
Nitzschia acicularis			0.6	
Nitzschia hanizschiana			2.5	
Nitzschia holsatica		3.3		
Oscillatoria sp.	x	0.7	37.7	x
Pediastrum		0.7	x	x
pennate diatom		0.7		
Raphidiopsis curvata			3.1	
Scenedesmus sp.	9.6	2.7	5.7	3.5
Schroederia setigera		1.3	0.6	
Skeletonema potamos		0.7	5.0	x
Stephanodiscus astraea		39.5		
Tetraedron minimum			1.3	
Tetrastrum staurogeniaeformi		0.7		
Trachelomonas		0.7		

STANDING CROP OF FISH: The fish resources of Grand Lake have been regularly sampled by the Oklahoma Department of Wildlife Conservation since 1949. The total pounds of fish per acre of water has not changed significantly since the collections were started (Table 69).

Table 69. Estimated Standing Crop of Fish (Aggus et al. 1982).

	Pounds Per Acre					
Species	1949	1957	1970	1973	1982	Ave.
paddlefish	0.1	-	0.4	-	-	0.1
spotted gar	-	-	-	-	0.8	0.2
longnose gar	0.2	t	0.4	0.2	0.1	0.2
gizzard shad	250.0	157.2	160.5	249.0	104.7	184.3
common carp	14.0	11.8	28.3	39.5	84.4	35.6
river carpsucker	20.8	6.4	7.2	22.9	18.2	15.1
spotted sucker	-	t	-	2.5	-	0.5
redhorses	1.0	8.4	-	-	-	1.9
smallmouth buffalo	31.9	25.5	50.8	88.2	57.7	50.8
bigmouth buffalo	-	-	-	2.1	-	0.4
channel catfish	19.8	7.8	12.3	12.6	31.7	16.8
flathead catfish	9.5	0.6	12.4	24.1	11.8	11.7
white bass	3.1	t	0.4	1.3	t	1.0
all sunfishes	13.9	15.5	47.8	50.7	53.7	36.5
spotted bass	1.5	t	t	t	1.2	0.5
largemouth bass	17.5	6.3	17.7	5.3	10.6	11.5
white crappie	8.3	8.9	21.7	39.8	37.1	23.2
logperch	2.1	-	-	0.3	0.4	0.6
freshwater drum	43.7	56.8	44.7	71.0	52.7	53.8
brook silverside	0.6	-	-	t	0.2	0.2
TOTAL CROP	438.0	305.5	404.6	610.3	465.3	444.8

OUTPUT 13: Alternatives for Lake Restoration

OBJECTIVE: To identify and discuss the alternatives considered for lake restoration and justify the selected alternatives.

DISCUSSION: Since the existing problems in Grand Lake appear to be heavy metal contamination in upper end of lake and nutrient enrichment, restoration remedies will be focused on two separate and distinct facets.

ALTERNATIVE 1: Prevention of Heavy Metal Contamination from Old Mining Operations.

The abandoned lead and zinc mines in both the Neosho River and the Spring River drainage basins contribute significant quantities of trace toxic metals to the upper end of Grand Lake. The bulk of the heavy metals precipitate into the sediments at the upper end of Grand Lake and thus do not currently represent a threat to the remainder of the Lake. However, there was an extremely sparse population of benthic macroinvertebrates in sediments at sampling station No. 1 at the upper end of Grand Lake. In six Ekman dredge samples, there were no macroinvertebrate organisms found in the sediments at station 1! The density appeared to be normal at stations 2, 3, and 4.

Considerable effort and money has been expended to contain acid mine seeps transporting high levels of heavy metals in the "Tar Creek" area. These efforts should be continued and expanded! If the concentrations of acidity and heavy metals were from a point source discharge, both the State and Federal regulatory agencies would implement fines and demand a compliance schedule to "clean-up" the contamination. This is a much more complicated problem and the magnitude of contamination is obviously much greater, but the mine seeps are a technical violation of the national laws of "no discharge of toxic substances in toxic amounts". Therefore, the State and Federal agencies must continue to attempt to contain and prevent any further deterioration of surface waters in the area.

ALTERNATIVE 2: Reduction of Nutrient Input from Agricultural Operations.

Grand Lake is also exhibiting symptoms of over fertilization (eutrophication) in several areas of the lake. The most prominant areas include the upper 1/6 of the main body of the lake and the following tributary arms; Elk River Arm and Honey Creek Arm. These areas contained levels of chlorophyll *a*, phosphorus, nitrogen, and reduced Secchi Disk reading sufficient to fall into the classification of eutrophic. The sources of nutrient input to Grand Lake are similar to that of many other reservoirs in the central plains states, i.e., nonpoint source runoff from agricultural activities and point source contributions from metropolitan areas. However, Grand Lake is also unique with respect to development of residential areas along the shoreline. Permission was granted by GRDA to develop both permanent and temporary residential areas in close proximity to the 100 year flood storage pool level of the lake. As a result, there are numerous homes along the shoreline of Honey Creek Cove, Elk River arm, and main part of the lake near Grove, OK. Most of these homes use a septic tank-lateral line system for disposal of domestic wastes. However, the geology of the area consists of very shallow soils overlying highly fractured rock formations, which severely restricts the efficiency of soil microbial degradation of domestic wastes.

We opted to use a relatively simple, but very useful, empirical model similar to that developed by Gachter and Imboden (1985). Their model was based upon the balance of phosphorus input and losses from a lake, i.e.;

$$P_{\infty} = P_{in} \frac{\rho}{\beta_{\rho} + \sigma}$$

Where;

P_{∞} = mean steady state concentration of total phosphorus in lake

P_{in} = mean concentration of total phosphorus input to lake

ρ = water renewal rate, i.e. Q/V

β = vertical form factor, P_o/P

P_o = mean total phosphorus in surface outflow

P = mean total phosphorus in lake

σ = net sedimentation rate

The trophic status of Grand Lake is a complex multidimensional dynamic state. The upper end of the lake becomes eutrophic as soon as turbidity decreases in the quiescent sections of the lake and sufficient light penetration can occur to stimulate algal growth in response to the nutrients carried by the riverine water. After the nutrients are tied up in algal biomass, the middle and lower sections of the lake tend to be either mesotrophic or oligotrophic, respectively. Results from seven intensive surveys of 90 sampling stations, conducted during 1985 and 1986, documented the establishment of similar longitudinal gradients in Lake Marion, and some minimal gradient development in Lake Moultrie, South Carolina (Pickett and Harvey 1988). Differences in reservoir morphometry and hydrodynamics are apparently responsible for this difference between lakes. Pronounced longitudinal gradients in Secchi transparency and in concentrations of total phosphorus, nitrate- nitrite nitrogen, and chlorophyll a were recorded for Grand Lake.

We elected to evaluate trophic status of the lake as a whole and also primarily by examining annual averages. This approach would hopefully eliminate some of the noise of daily or weekly variations in concentration of nutrients.

We used the statistical/empirical models developed by Reckhow (1988) from data collected by EPA during the national eutrophication survey on a series of reservoirs in the southeastern United States. Reckhow analyzed a cross-sectional data set of 80 lakes and reservoirs in nine southeastern states with an empirical model, which was then statistically optimized to fit the field data sets. The resultant trophic state models related phosphorus and nitrogen loading to inlake phosphorus and nitrogen concentrations, which were also related to maximum chlorophyll level, Secchi disk depth, dominant algal species, and hypolimnetic dissolved oxygen status. This model showed sufficient correlation with observed field data collected on Grand Lake to permit realistic predictions of changes in trophic status in response to various nutrient reduction plans.

The best fit model for phosphorus was calculated to be:

$$k = 3.0(P_{in})^{0.53} (T_w)^{-0.75} (z)^{0.58} \quad (1)$$

Where

k =phosphorus trapping paramater

P_{in} =mean annual influent total phosphorus conc. (mg/l)

T_w = hydraulic retention time (yr)

z = mean depth (m)

The combined data set of measured concentration of total phosphorus at the upper most station (station 1) on Grand Lake was analyzed to determine the 0.25, 0.50, and 0.75 quartile distribution for the total period of study. A random number generator function was utilized to generate 100 values between the measured 0.25 and the 0.75 quartile distributions. The median value of the generated data set was selected to represent the mean annual input of phosphorus. Reckhow's (1) equation was then applied to the data set to establish predicted mean annual concentration of chlorophyll *a* (as ug/l) with no change and with reductions of phosphorus or nitrogen. The same calculations were applied to predict changes in chlorophyll *a* in response to selected reductions in phosphorus or nitrogen.

Reduction of mean annual total phosphorus by 60% would be required to achieve an "in-lake" concentration of 0.020 mg/l. The effects of reducing phosphate within Grand Lake are predicted in Figure 68. The predicted

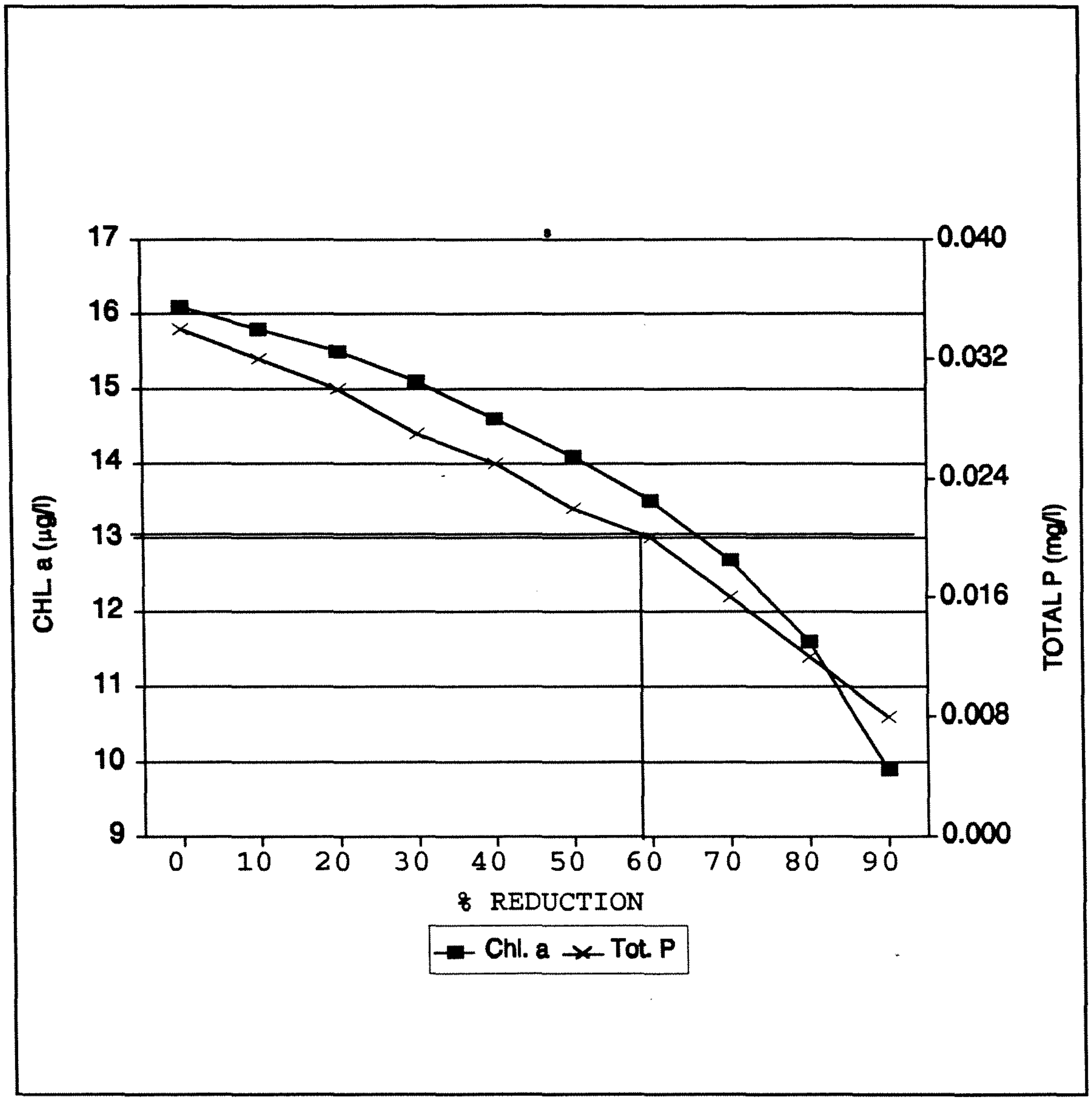


Figure 68. Predicted concentration of chlorophyll *a* in Grand Lake after phosphate reductions.

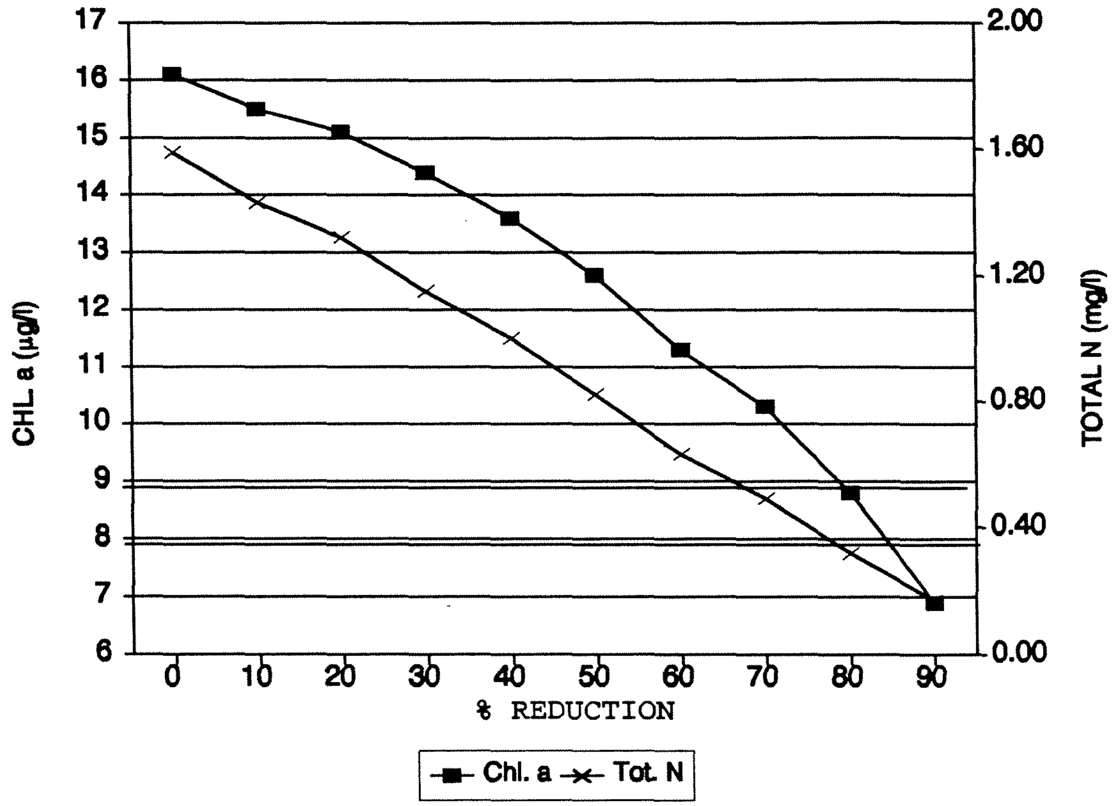


Figure 69. Predicted chlorophyll *a* concentration in Grand Lake after nitrogen reductions.

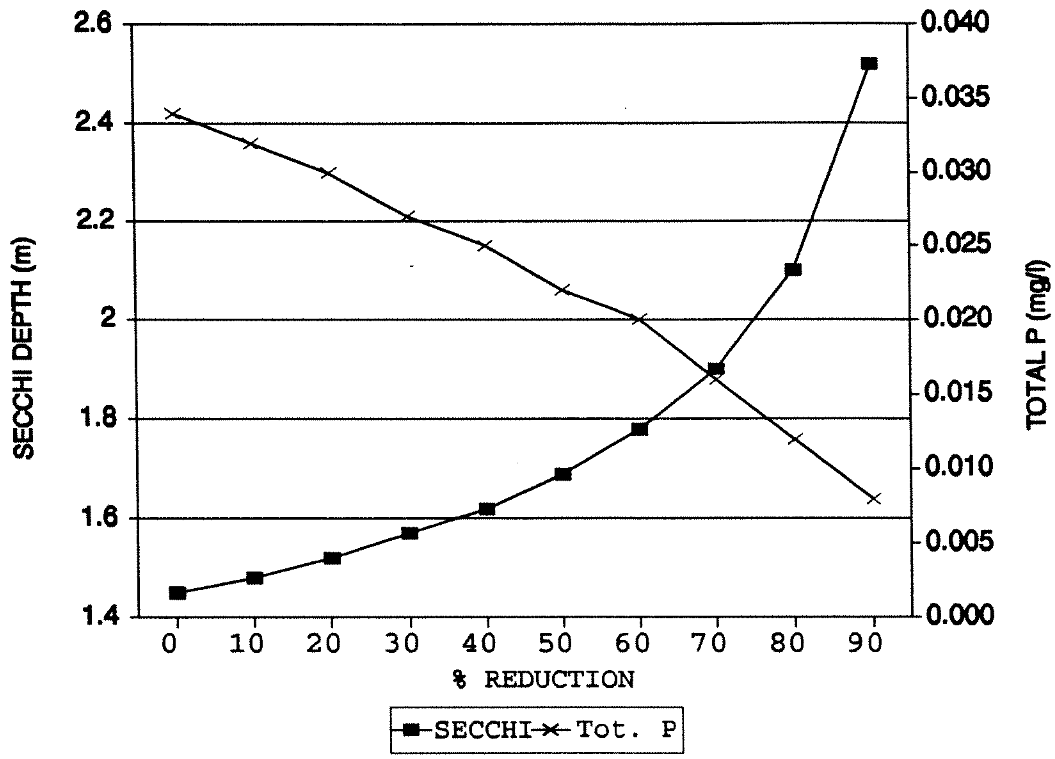


Figure 70. Predicted secchi depth after reduction of phosphates in Grand Lake.

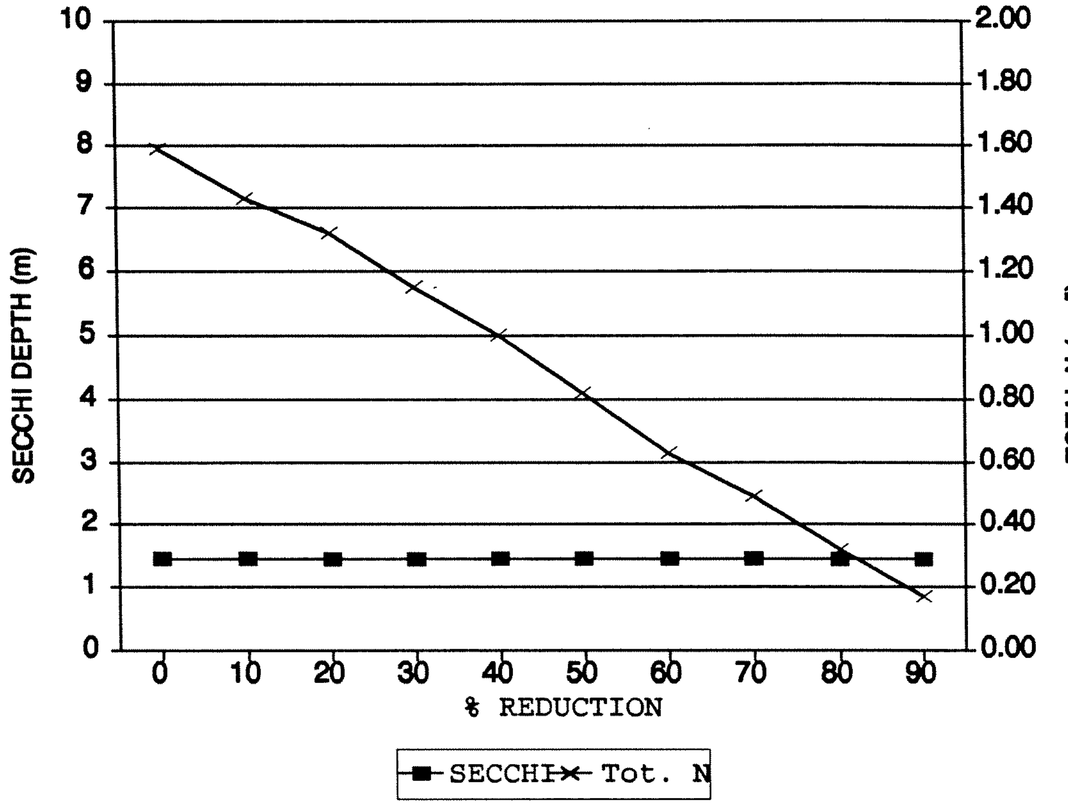


Figure 71. Predicted secchi depth after reduction in nitrogen in Grand Lake.

changes in chlorophyll a were derived from Reckhow's equations, by arbitrarily reducing the mean annual total phosphate concentration by percentages ranging from 10 to 100% at increments of 10%.

The probability that anoxic conditions will continue in the hypolimnetic waters of Grand Lake were predicted with Rechkow's equations. Obviously, there are many other factors which may influence development of anoxic conditions in the hypolimnion of lakes, however we believe the conditions predicted in this report are restricted to those influences that nutrients might have on stimulating algal growth. These predictions would thus tend to be conservative and would not reflect the potential contribution of other organic "oxygen demanding" waste materials from other sources.

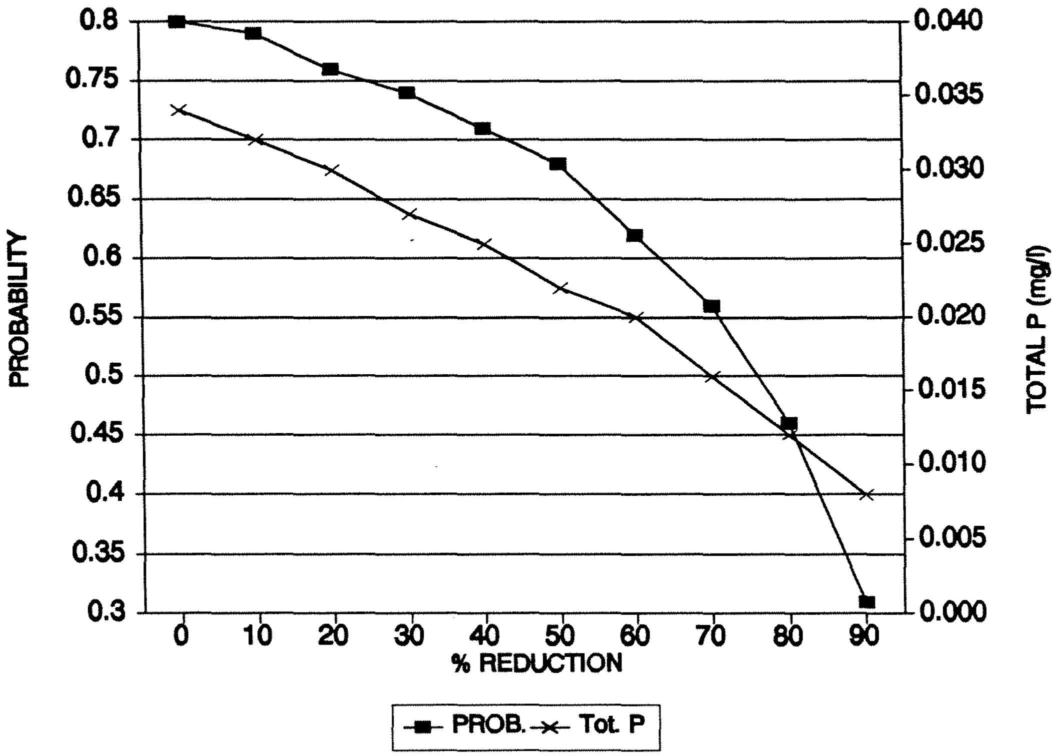


Figure 72. Probability of anoxic conditions developing in the hypolimnion of Grand Lake after phosphate reductions.

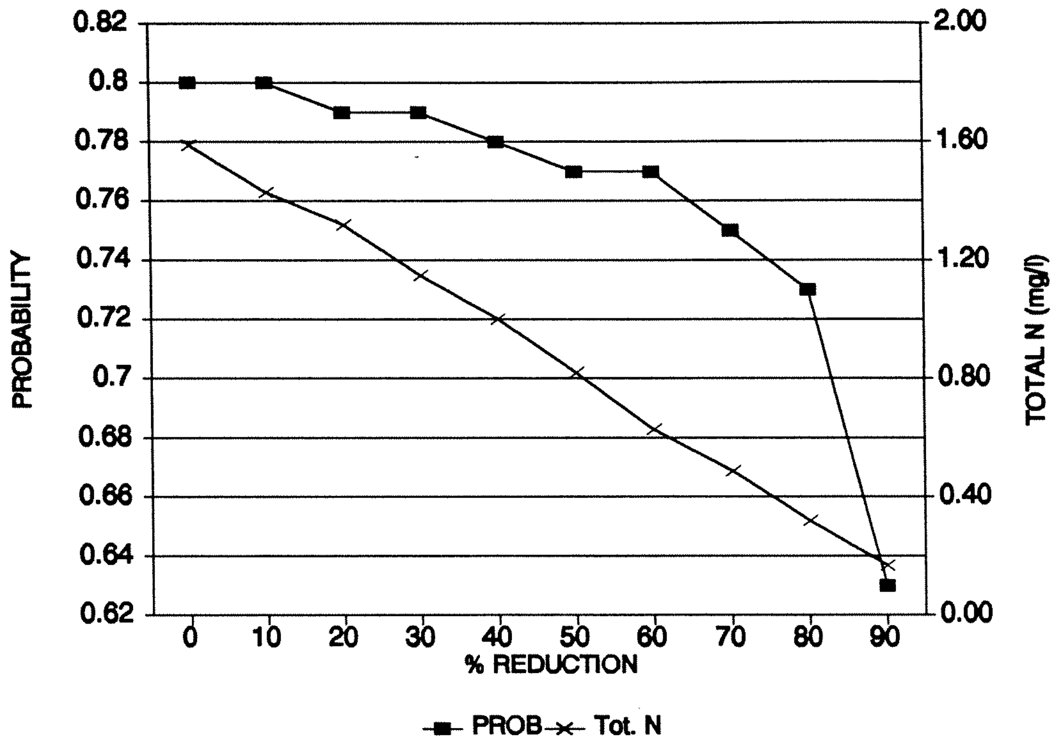


Figure 73. Probability of anoxic conditions developing in Grand Lake after nitrogen reductions.

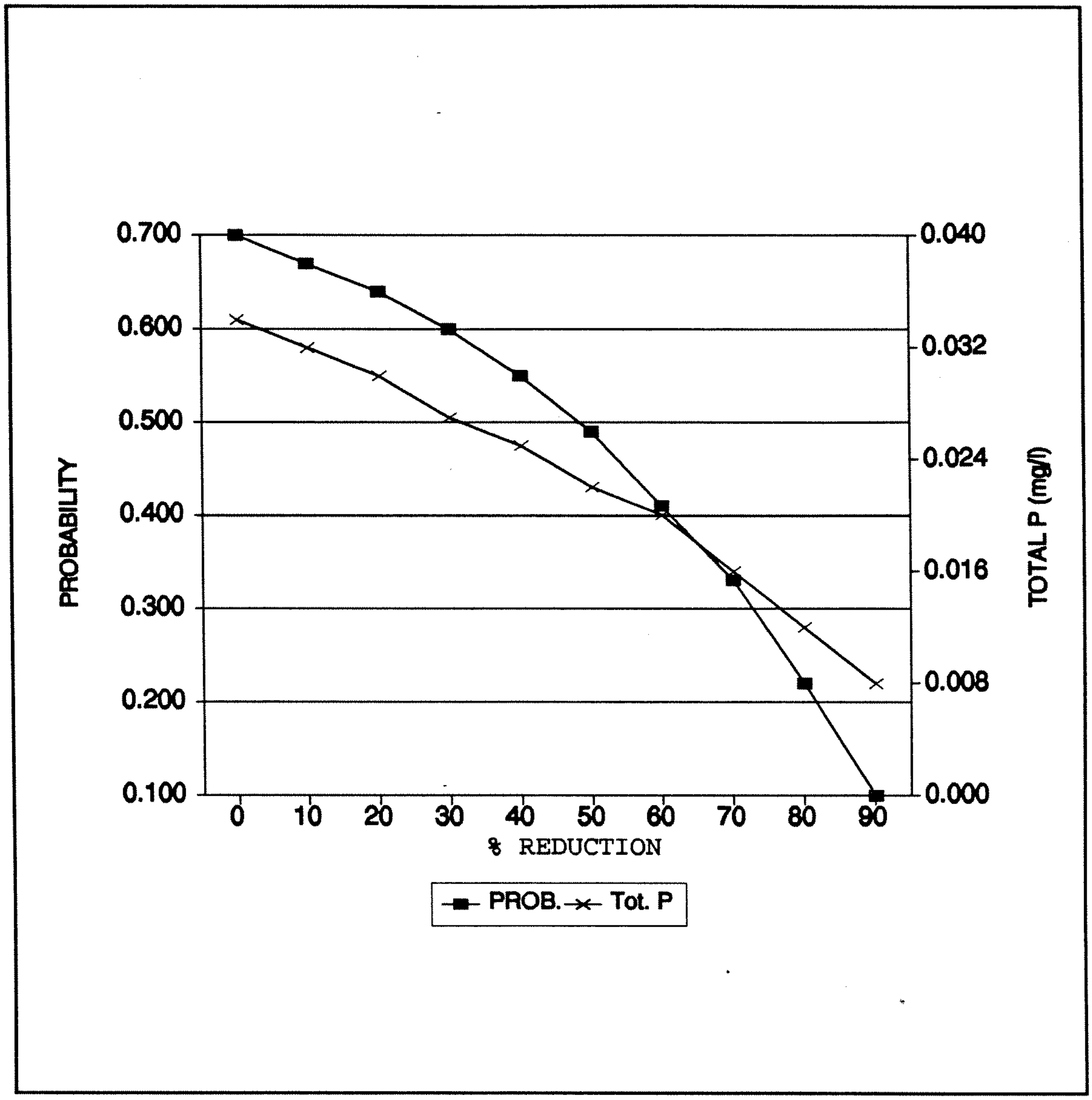


Figure 74. Probability of blue green algae becoming dominant after phosphate reductions in Grand Lake.

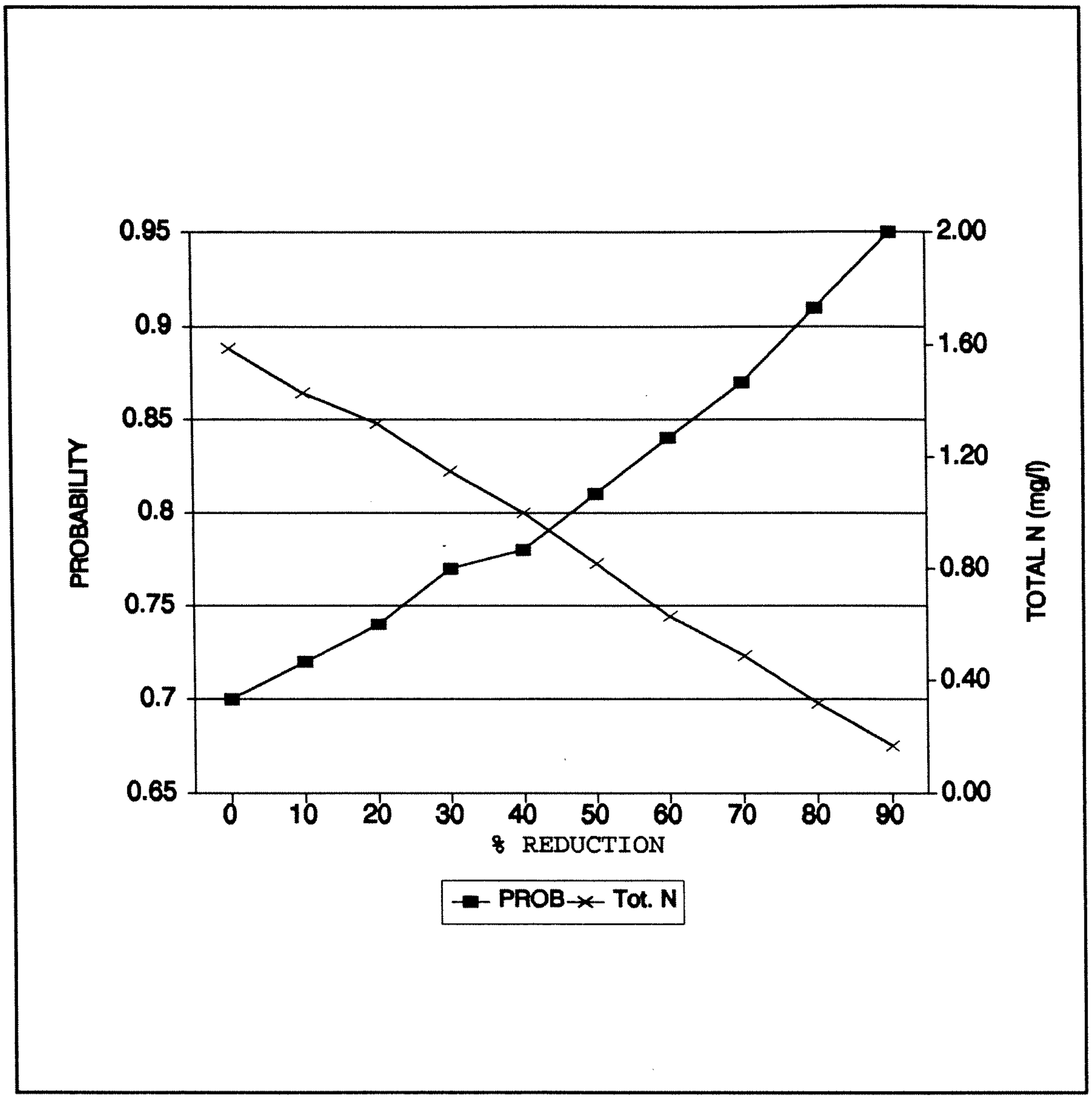


Figure 75. Probability of blue green algae becoming dominant after nitrogen reductions in Grand Lake.

OUTPUT 14: Benefits of Restoration

OBJECTIVE: To discuss potential benefits accruing from implementation of the restoration projects.

DISCUSSION: Improved water quality should enhance recreational use of Grand Lake. Also, enhanced water quality would provide greater potential for additional beneficial uses of the lake.

METHOD: Evaluation of data from TASK 6 and input from the Grand Lake Resort Owners Association, GRDA, and city-county-state agencies.

TASK 15: Phase 2 Monitoring Program

OBJECTIVE: To design a Phase 2 Monitoring Program

DISCUSSION: A monitoring program will developed to assess the improvements in water quality of any restorative measures implemented. Also the monitoring program will record any temporary adverse effects upon water quality.

METHOD: Federal Register 45(25):798-799 (Phase 2 Procedures)

TASK 16: Milestone Work Schedule

OBJECTIVE: To provide a proposed milestone work schedule for completing the project with a proposed budget and payment schedule.

METHOD: Based upon the best alternative selected in OUTPUT 13, the proposed schedule will be developed for construction or renovation- remediation projects.

TASK 17: Non-Federal Funding

OBJECTIVE: To propose sources for obtaining nonfederal funding for required matching costs of restoration.

METHOD: Consultation with administrators of GRDA, Grand Lake Resort Owners Association, and appropriate legislators from the Grand Lake area.

TASK 18: Project Relationship to Other Pollution Control Programs

OBJECTIVE: To describe the relationship of the proposed project to other pollution control programs.

METHOD: Compatibility of proposed restoration program to other state/federal agency pollution control programs.

OUTPUT 19: Public Participation

OBJECTIVE: Establish public participation in developing and assessing the propos ed project .

METHOD: A synopsis of public response and participation in the assessment of the proposed project. In compliance with Part 25 of Federal Register 45(25), shall include the subjects presented to the public, the actions taken by the reporting agency to fulfill its obligations under Part 25, and related provisions; the public response; and the agency's response to significant comments.

OUTPUT 20: State Operation and Maintenance Plan

OBJECTIVE: Description of State Operation and Maintenance plans to implement restoration project.

METHOD: Describe the State's Operation and Maintenance plan for insuring that the reduction and/or prevention of contamination controls are continued after the project is completed.

OUTPUT 21: Permits

OBJECTIVE: Make application for all necessary permits.

METHOD: Ascertain and make application for all permits necessary for implementation of the restoration program, in accordance with section 404 of the Clean Water Act.

TASK 22: Environmental Evaluation

OBJECTIVE: Completion of the Environmental Evaluation

METHOD: Evaluate the potential effect of the restoration project upon the following specific areas:

1. Displacement of people.
2. Changes in established land use patterns such as increased development pressure near the lake.
3. Cause devaluation of existing residences or residential areas.
4. Cause adverse impact upon agricultural practices in the watershed.
5. Cause adverse impact upon parks or other public facilities.
6. Any impacts predicted by officials of the State Historical Society, State Preservation Society, or Archaeological Society.
7. Significant increase in energy consumption.
8. Significant impact upon air quality or noise pollution?
9. Chemical treatments effects on upon water quality of the lake.
10. Compliance of project with EPA requirements on floodplains (Executive Order 11988).
11. Short-term or long-term impact of dredging.
12. Compliance with EPA Executive Order 11990 requirements on wetlands?
13. Evaluation of alternatives; environmental impact, commitment of resources, and public interest & costs.
14. Evaluation of other measures necessary to minimize environmental impact of restoration project.

Literature Cited

Adams, W. J., Ziegenfuss, S. P., Renaudette, W. J., and R. G. Mosher. 1985. Comparison of laboratory and field methods for testing the toxicity of chemicals sorbed to sediments. In T. M. Poston, and R. Purdy, eds., Aquatic Toxicology and Environmental Fate, 9th Volume. pp. 494-514.

Aggus, L. R., Vogele, L. E., Rainwater, W. C., and D. I. Morrais. 1982. Effects of acid-mine drainages from Tar Creek on fishes and benthic macroinvertebrates in Grand Lake, Oklahoma. Oklahoma Tar Creek Environmental Effects Subcommittee, Oklahoma City, OK

Benoit, R. J., J. C. Cairns, Jr., and C. W. Riemer. 1969. A limnological reconnaissance of an impoundment receiving heavy metals, with emphasis on diatoms and fish. In Aggus, et al., Effects of acid-mine drainages from Tar Creek on fishes and benthic macroinvertebrates in Grand Lake, Oklahoma. p. 44. Oklahoma Tar Creek Environmental Effects Subcommittee, Oklahoma City, OK.

Benoit, D. A., Leonard, E. N., Christensen, G. M., and J. T. Fiandt. 1976. Toxic effects of Cd on three generations of brook trout (Salvelinus fontinalis). Trans. Am. Fish. Soc. 105:550-560.

Bradley, R. W., and J. R. Morris. 1986. Heavy metals in fish from a series of metal-contaminated lakes near Sudbury, Ontario. Water Air Soil Pollut. 27:34-354.

Carlson, R.E. 1977. A trophic state index for lakes. Limnol. & Oceanogr. 23:361-369.

Chapra, S.C. and K.H. Reckhow. 1983. Engineering Approaches for Lake Management. Vol. 2: Mechanistic Modeling, Butterworth Publishers, Inc., Boston, MA. 1-492.

Chapman, Peter M. 1986. Sediment quality criteria from the sediment quality triad: an example. Environ Toxicol and Chem. 5:957-964.

Dallinger, R., and H. Kautzky. 1985. The importance of contaminated food for the uptake of heavy metals by rainbow trout (Salmo gairdneri): a field study. Oecologia 67:82-89.

Dawson, D. A., Stebler, E. F., and S. L. Burks. 1988. Evaluation of the developmental toxicity of metal-contaminated sediments using short-term fathead minnow and frog embryo-larval assays. Environ Toxicol and Chem. 7:27-34.

DiToro, D. M., and L. M. Horzempa. 1982. Reversible and resistant components of PCB adsorption and desorption: Isotherms. Environ. Sci. Tech. 6:594-602.

DiToro, D. M. 1989. 10th Annual Meeting of Society of Environmental Toxicology and Chemistry. Personal communication.

Eaton, J. G. 1974. Chronic Cd toxicity to the bluegill (Lepomis macrochinus Rafinesque). Trans. Am. Fish. Soc. 103:729-735.

Edgren, M. and M. Notter. 1980. Cd uptake by fingerlings of perch (Perca fluviatilis) studied by Cd-115 at two different temperatures. Bull. Environ. Contam. Toxicol. 24: 647-657.

Florence, T. M., and G. E. Batley. 1980. Chemical speciation in natural waters. CRC Crit. Rev. Anal. Chem. 9:219-296.

Forstner, U., and F. Prosi. 1979. Heavy metal pollution in freshwater ecosystems. In O. Ravera, ed., Biological Aspects of Freshwater Pollution. Pergamon Press, New York, N. Y., pp. 129-161.

Giesy, J. P., Graney, R. L., and J. L. Newsted. 1988. Comparison of three sediment bioassay methods using Detroit River sediments. Environ. Toxicol. 7:483-498.

Grahl, K., Franke, P., and R. Hallebach. 1985. The excretion of heavy metals by fish. In J. Salanki, ed., Heavy Metals in Water Organisms. Akademiai Kiado, Budapest, p. 361.

Gulley, D. D., A. M. Boelter, and H. L. Bergman. 1989. TOXSTAT/DATASYS statistical software, Release 3.0. Department of Zoology and Physiology, University of Wyoming, Laramie, Wyoming.

Hatakeyama, S. and M. Yasuno. 1982. Accumulation and effects of Cd on guppy (Poecilia reticulata) fed cadmium-dosed cladocera (Moina macrocopa). Bull. Environ. Contam. Toxicol. 29:159-166.

Jenne, E. A., and S. N. Luoma. 1977. Forms of trace elements in soils, sediments and associated waters: An overview of their determination and biological availability. In J. O. Nriagu, and J. B. Sprague, eds., Cadmium in the Aquatic Environment. John Wiley & Sons, New York, NY, p. 90.

Kumada, H., Kimura, S., and M. Yokote. 1980. Accumulation and biological effects of Cd in rainbow trout. In J. O. Nriagu, and J. B. Sprague, eds., Cadmium in the Aquatic Environment. John Wiley & Sons, New York, NY, p. 103.

Loftis, J.C. Phillips, R.D., Ward, R.C. and Taylor, C.H. 1989. WQSTAT II: A water quality statistics package. Groundwater 27:866-873

Mance, G. 1987. Pollution Threat of Heavy Metals in Aquatic Environments. Elsevier Applied Science, New York, NY.

McCormick, C. A. 1985. Water quality and sediments of an area receiving acid-mine drainage in northeastern Oklahoma. M.S. Thesis. Oklahoma State University, Stillwater, Ok.

Phillips, R.D., Hotto, H.P., and Loftis, J.C. 1989. WQSTAT II: A Water Quality Statistics Program Owners Manual. Colorado State Univ., CO.

O'Donnell, J. R., Kaplan, B. M., and H. E. Allen. 1985. Bioavailability of trace metals in natural waters. In R. D. Cardwell, R. Purdy, and A. C. Bahner, eds., Aquatic Toxicology and Hazard Assessment, 7th Symposium. ASTM, Baltimore, pp. 483- 500.

Oklahoma Water Resources Board. 1981. Summary of Data Collected by Governor's Tar Creek Task Force Regarding Groundwater Discharge from Abandoned Lead and Zinc Mines of Ottawa County, Oklahoma.

Part, P., and O. Svanberg. 1981. Uptake of Cd in perfused rainbow trout (Salmo gairdneri) gill. Can. J. Fish. Aquat. Sci. 38:917-924.

Roch, M., Noonan P., and J. A. McCarter. 1986. Determination of no-effect levels of heavy metals for rainbow trout using hepatic metallothionein. Water Res. 20:771-774.

Salomons, W., de Rooij, N. M., Kerdijk, H., and J. Bril. 1987. Sediments as a source of contaminants? Hydrobiologia. 149:13-30.

Sangaland, G. B., and H. C. Freeman. 1979. Tissue uptake of Cd in brook trout during chronic sublethal exposure. Arch. Environ. Contam. Toxicol. 8:77-84.

Sorenson, K. 1989. Oklahoma State University Fish and Wildlife Cooperative. Personal communication.

Tessier, A., and P. G. C. Campbell. 1987. Partitioning of trace metals in sediments: Relationships with bioavailability. Hydrobiologia. 149:43- 52.

Thomas, D. G., Solbe, J. F., deL. G., Kay, J., and A. Cryer. 1983. Environmental Cd is not sequestered by metallothionein in rainbow trout. Biochem. Biophys. Res. Commun. 110:584-592.

United States Environmental Protection Agency. 1979. Methods for the Chemical Analysis of Water and Wastes. EPA-600 4-79-020.

United States Environmental Protection Agency. 1982. Test Methods for Evaluating Solid Waste. EPA/SW-846.

United States Environmental Protection Agency. 1989. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Fresh water Organisms. EPA 600/4-85-014.

Williams, D. R., and J. P. Giesy. 1978. Relative importance of food and water sources to Cd uptake by Gambusia affinis (Poeciliidae). Environ. Res. 16: 326-382.

United States Environmental Protection Agency. 1986. Quality Criteria for Water 1986. EPA 440/5-86-001.

United States Geological Survey. National Sediment Criteria 1977. In United States Environmental Protection Agency, Region VI, Dallas, TX. Proposed toxic criteria for water, fish tissue, and sediments.

Ziegenfuss, S, Renaudette, W. J., and W. J. Adams. 1986. Methodology for testing the acute toxicity of chemicals sorbed to sediments: Testing the equilib- rium partitioning theory. In T. M. Poston, and R. Purdy, eds., Aquatic Toxicology and Environmental Fate, 9th Volume. pp. 479-493.

APPENDIX A:

FIELD LIMNOLOGICAL DATA FOR GRAND LAKE

Table A1.. WQRL field data summary for Grand Lake station 1.

DATE	LOCATION	TURBIDITY (NTU)	SP.COND. (μmho/cm)	pH (S.U.)	SECCHI DISK (cm)
09-May-89	SURFACE	--	392	7.0	30.4
	BOTTOM	--	--	--	--
06-Jun-89	SURFACE	24.8	363	7.2	25.4
	BOTTOM	--	--	--	--
21-Jun-89	SURFACE	36.0	390	7.8	25.4
	BOTTOM	58.0	390	7.7	--
20-Jul-89	SURFACE	126.0	262	7.9	10.1
	BOTTOM	146.0	261	7.4	--
10-Aug-89	SURFACE	39.0	256	8.0	35.5
	BOTTOM	64.0	253	7.9	--
07-Sep-89	SURFACE	75.0	--	--	12.7
	BOTTOM	77.0	--	--	--
02-Oct-89	SURFACE	22.0	320	7.9	45.7
	BOTTOM	81.0	--	--	--
10-Jul-90	SURFACE	24.3	--	--	--
	BOTTOM	--	--	--	--
22-Aug-90	SURFACE	25.1	--	--	--
	BOTTOM	--	--	--	--

Table A2.. WQRL field data summary for Grand Lake station 2.

DATE	LOCATION	TURBIDITY (NTU)	SP. COND. (μmhos/cm)	pH (S.U.)	SECCHI DISK (cm)
09-May-89	SURFACE	--	290	--	83.8
	BOTTOM	--	304	--	--
05-Jun-89	SURFACE	--	--	--	35.5
	BOTTOM	--	--	--	--
21-Jun-89	SURFACE	18	270	8.45	35.5
	BOTTOM	45	270	--	--
21-Jul-89	SURFACE	13	--	--	58.4
	BOTTOM	46	255	--	--
10-Aug-89	SURFACE	19	301	9.0	63.5
	BOTTOM	72	325	6.8	--
07-Sep-89	SURFACE	31	--	7.8	10.1
	BOTTOM	60	--	--	--
02-Oct-89	SURFACE	14	257	8.1	--
	BOTTOM	93	--	7.3	--
10-Jul-90	SURFACE	16	--	--	--
	BOTTOM	--	--	--	--
23-Aug-90	SURFACE	8	--	--	76.2
	BOTTOM	--	--	--	--

Table A3.. WQRL field data summary for Grand Lake station 3.

DATE	LOCATION	TURBIDITY (NTU)	SP.COND. (µmho/cm)	pH (S.U.)	SECCHI DISK (cm)
06-Jun-89	SURFACE	2.6	--	--	167.6
	BOTTOM	17.5	--	--	--
22-Jun-89	SURFACE	3.8	269	8.1	142.2
	BOTTOM	11.0	268	6.5	--
20-Jul-89	SURFACE	3.9	250	--	124.4
	BOTTOM	5.1	250	--	--
10-Aug-89	SURFACE	7.0	270	8.3	119.3
	BOTTOM	11.0	230	6.5	--
08-Sep-89	SURFACE	6.8	--	--	96.5
	BOTTOM	25.0	--	--	--
02-Oct-89	SURFACE	8.0	262	7.9	147.3
	BOTTOM	57.9	291	7.4	--
10-Jul-90	SURFACE	10.0	--	--	--
	BOTTOM	--	--	--	--
23-Aug-90	SURFACE	7.0	--	--	137.1
	BOTTOM	--	--	--	--

Table A4.. WQRL field data summary for Grand Lake station 4.

DATE	LOCATION	TURBIDITY (NTU)	SP.COND. (µmho/cm)	pH (S.U.)	SECCHI DISK (cm)
05-May-89	SURFACE	--	228	7.9	--
	BOTTOM	--	--	--	--
06-Jun-89	SURFACE	3.6	--	--	243.8
	BOTTOM	10.2	--	--	--
21-Jun-89	SURFACE	4.1	250	8.3	129.5
	BOTTOM	9.4	260	7.7	--
20-Jul-89	SURFACE	4.1	247	8.3	152.4
	BOTTOM	3.3	--	--	--
11-Aug-89	SURFACE	5.2	256	8.3	139.7
	BOTTOM	6.7	268	7.0	--
02-Oct-89	SURFACE	5.0	228	8.2	180.3
	BOTTOM	--	231	7.5	--
23-Aug-90	SURFACE	--	--	--	--
	BOTTOM	--	--	--	--

Table A5. WQRL temperature/dissolved oxygen profile data for Grand Lake station 1.

DATE	DEPTH[1] (m)	D.O. (mg/l)	TEMP. (C)
06-Jun-89	1	7.7	24.8
	2	7.7	24.9
	3	7.5	24.8
	4	7.1	24.7
	5	6.9	24.6
	6	6.7	24.5
	6.5	6.7	24.5
21-Jun-89	1	9.3	28.0
	3	7.8	27.2
	4	7.6	26.8
	5	7.5	26.5
	6	6.2	26.0
	7	5.8	25.5
	8	5.2	25.2
	9	4.4	25.0
	10	4.2	24.7
	11	3.8	24.2
	12	3.8	24.2
	13	3.6	24.0
	14	3.4	24.0
	15	3.4	24.0
	16	3.0	24.0
	17	2.8	23.8
	18	2.6	23.8
	19	2.5	23.8
	20	2.0	23.8
	21	1.2	23.8
20-Jul-89	1	5.8	24.0
	2	5.8	24.0
	3	5.3	24.0
	4	5.2	24.0
	5	5.2	24.0
	6	5.1	24.1
	7	5.1	24.1
10-Aug-89	1	6.7	27.0
	2	5.4	26.8
	3	3.6	26.6
	4	2.9	26.4
	5	3.1	26.0
	6	3.0	25.8
	7	1.8	25.6

Table A5. Continued....

DATE	DEPTH[2] (m)	D.O. (mg/l)	TEMP. (C)
02-Oct-89	1	11.9	16.9
	2	9.9	16.2
	3	6.0	14.9
	4	5.2	14.2
	5	5.1	14.2
	6	4.2	14.2
	7	0.0	14.2
	8	0.0	14.2

Table A6. WQRL temperature/dissolved oxygen profile data for Grand Lake station 2.

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
09-May-89	0	10.0	18.4
	1	9.5	18.4
	2	9.5	18.4
	3	9.4	18.4
	4	9.4	18.4
	5	7.4	18.4
21-Jun-89	1	8.0	26.0
	2	8.0	26.0
	3	7.4	26.0
	4	7.4	26.0
	5	7.4	25.2
	6	7.4	25.0
	7	7.4	25.0
	8	7.4	25.0
	9	7.2	25.0
	10	6.8	25.0
	11	6.8	24.8
	12	6.5	24.5
	13	5.6	24.0
	14	4.8	23.2
	15	4.6	23.0
	16	4.4	23.0
	17	4.2	23.0
	18	3.8	22.8
	19	3.1	22.0
	20	2.8	21.5
	21	2.8	21.5
	22	2.7	21.5
	23	2.8	21.5
	24	2.7	21.5

Table A6. Continued...

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
	25	2.6	21.2
	26	2.4	21.0
	27	2.3	21.0
	28	2.0	21.0
	29	1.8	21.0
	30	1.7	21.0
	31	1.6	21.0
	32	1.3	20.8
	33	1.1	20.5
	34	0.7	20.5
	35	0.5	20.2
	36	0.5	20.0
	37	0.2	20.0
	38	0.2	20.0
	39	0.2	20.0
	40	0.2	20.0
	41	0.2	20.0
	42	0.2	20.0
	43	0.2	20.0
	44	0.2	20.0
	45	0.2	20.0
	46	0.1	20.0
	47	0.1	20.0
	48	0.1	20.0
	49	0.0	20.0
	50	0.0	20.0
	51	0.0	20.0
	52	0.0	20.0
	53	0.0	20.0
	54	0.0	20.0
	55	0.0	20.0
	56	0.0	19.5
	57	0.0	19.5
	58	0.0	19.5
	59	0.0	19.5
	60	0.0	19.5
	61	0.0	19.5
	62	0.0	19.5
	63	0.0	19.2
	64	0.0	16.5

Table A6. Continued...

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
21-Jul-89	1	7.0	24.5
	2	6.5	24.3
	3	6.5	24.1
	4	6.0	24.0
	5	5.7	24.0
	6	5.2	24.0
	7	4.7	23.8
	8	3.1	23.2
	9	2.3	23.0
	10	0.0	21.5
	11	0.0	20.9
	12	0.0	20.2
	13	0.0	19.9
	14	0.0	19.4
	15	0.0	19.4
	16	0.0	19.4
10-Aug-89	1	10.0	25.0
	2	6.4	24.1
	3	5.5	24.1
	4	5.2	24.0
	5	5.3	24.0
	6	5.3	23.9
	7	5.4	23.9
	8	5.1	23.5
	9	3.5	23.5
	10	2.8	23.1
	11	2.8	23.1
	12	1.3	22.0
	13	0.6	21.4
	14	0.3	21.1
	15	0.1	20.9
	16	0.1	20.0
	17	0.2	19.5
	18	0.0	18.5
	19	0.0	17.8

Table A6. Continued...

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
02-Oct-89	1	8.5	18.1
	2	8.3	18.0
	3	7.9	17.8
	4	6.5	16.1
	5	5.2	16.5
	6	4.9	16.1
	7	4.8	16.1
	8	4.4	16.1

9	3.5	15.9
10	3.1	15.7
11	2.9	15.5
12	2.1	15.5
13	2.0	15.2
14	1.2	15.0
15	1.1	14.9
16	1.0	14.9
17	0.9	14.9
18	1.0	14.9
19	0.1	14.9
20	0.0	14.9
21	0.0	14.9
22	0.0	14.9
23	0.0	14.9
24	0.0	14.9
25	0.0	14.9
26	0.0	14.9
27	0.0	14.9
28	0.0	14.9
29	0.0	14.9

Table A7. WQRL temperature/dissolved oxygen profile data for Grand Lake station 3.

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
22-Jun-89	1	9.4	23.2
	2	9.3	23.1
	3	9.2	23.1
	4	9.1	23.1
	5	9.0	23.1
	6	8.6	23.0
	7	8.4	23.0
	8	8.1	23.0
	9	8.2	23.0
	10	8.1	23.0
	11	7.9	23.0
	12	8.1	22.9
	13	8.0	23.0
	14	7.7	22.9
	15	6.3	22.5
	16	6.0	22.3
	17	5.7	22.0
	18	5.6	22.0
	19	5.4	22.0
	20	5.1	22.0
	21	4.6	21.9
	22	4.5	21.5
	23	4.3	21.5
	24	4.4	21.5
	25	4.3	21.5
	26	3.9	21.3
	27	3.8	21.2
	28	3.7	21.1
	29	3.6	21.2
	30	3.6	21.1
	31	3.6	21.1
	32	3.6	21.1
	33	3.4	21.0
	34	3.2	21.0
	35	3.1	21.0
	36	3.1	21.0
	37	3.1	20.9
	38	3.0	20.9
	39	3.0	20.9
	40	2.9	20.9
	41	2.9	20.9
	42	2.8	20.9
	43	2.8	20.9
	44	2.8	20.9
	45	2.5	20.9

Table A7. Continued....

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
	46	1.2	20.0
	47	1.0	20.0
	48	0.8	19.9
	49	0.6	19.9
	50	0.4	19.1
	51	0.0	18.9
	52	0.0	18.9
	53	0.0	18.5
	54	0.0	18.0
	55	0.0	17.5
	56	0.0	17.1
	57	0.0	16.8
	58	0.0	16.2
	59	0.0	16.1
	60	0.0	16.0
	61	0.0	15.9
	62	0.0	15.9
	63	0.0	15.5
	64	0.0	15.0
20-Jul-89	1	7.2	24.1
	2	7.5	24.1
	3	7.2	24.0
	4	6.5	24.0
	5	6.2	24.0
	6	6.2	23.8
	7	5.5	23.8
	8	5.2	23.8
	9	5.0	23.8
	10	5.5	23.8
	11	4.7	23.8
	12	0.0	20.8
	13	0.0	20.1
	14	0.0	19.9
	15	0.0	19.9
	16	0.0	19.5
	17	0.0	19.2
	18	0.0	19.0
	19	0.0	17.5
	20	0.0	16.2
	21	0.0	15.0
10-Aug-89	1	9.5	24.5
	2	8.2	24.1
	3	7.5	24.0
	4	7.1	23.9
	5	6.5	23.8
	6	5.6	23.8
	7	4.6	23.6

Table A7. Continued....

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
	8	4.4	23.4
	9	4.3	23.2
	10	4.2	23.1
	11	3.2	23.1
	12	2.6	22.8
	13	2.0	22.5
	14	0.3	20.0
	15	0.1	20.0
	16	0.0	19.0
	17	0.0	18.8
	18	0.0	18.3
	19	0.0	17.9
	20	0.0	16.5
	21	0.0	16.1
	22	0.0	14.9
	23	0.0	14.9
	24	0.0	15.0
	25	0.0	15.0
08-Sep-89	1	5.4	27.8
	2	5.3	27.7
	3	5.1	27.7
	4	4.8	28.8
	5	4.9	28.7
	6	4.9	28.6
	7	4.1	--
02-Oct-89	1	7.0	22.2
	2	5.9	22.1
	3	5.9	22.0
	4	5.8	22.1
	5	5.7	22.0
	6	5.7	21.9
	7	5.7	21.9
	8	5.9	22.0
	9	5.8	21.9
	10	5.8	21.9
	11	5.8	21.9
	12	5.9	21.9
	13	5.1	21.4
	14	4.8	21.2
	15	4.8	21.1
	16	4.7	21.1
	17	4.2	20.9
	18	3.7	20.7
	19	3.5	20.5
	20	3.4	20.5
	21	2.8	20.1
	22	2.4	19.8

Table A7. Continued....

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
	23	2.2	19.7
	24	1.7	19.5
	25	1.5	19.4
	26	1.0	19.3
	27	0.5	18.8

Table A8. WQRL temperature/dissolved oxygen profile data for Grand Lake station 4.

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
21-Jun-89	1	12.0	25.5
	2	12.0	25.5
	3	12.4	25.0
	4	12.4	25.0
	5	12.4	25.0
	6	12.2	25.0
	7	12.4	25.0
	8	12.2	25.0
	9	12.0	24.5
	10	11.2	24.2
	11	10.8	24.0
	12	8.8	23.2
	13	6.8	22.5
	14	6.2	22.0
	15	6.1	22.0
	16	5.9	22.0
	17	5.8	22.0
	18	5.4	22.0
	19	5.5	22.0
	20	5.3	22.0
	21	5.2	22.0
	22	5.2	22.0
	23	5.0	22.0
	24	5.0	21.9
	25	4.8	21.9
	26	5.0	21.9
	27	4.8	21.8
	28	5.0	21.8
	29	5.0	21.8
	30	5.0	21.8
	31	4.8	21.5
	32	4.4	21.5
	33	4.6	21.5
	34	4.4	21.2
	35	4.2	21.2
	36	4.1	21.2
	37	3.9	21.0
	38	3.7	21.0
	39	3.6	21.0
	40	3.4	21.0
	41	3.0	21.0
	42	2.4	20.9
	43	2.2	20.5
	44	1.8	20.2
	45	1.3	20.0
	46	0.8	19.2

Table A8. Continued....

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
	47	0.5	18.5
	48	0.5	18.5
	49	0.6	18.2
	50	0.6	18.0
	51	0.6	18.0
	52	0.6	17.5
	53	0.9	17.0
	54	0.5	17.0
	55	0.8	16.5
	56	0.8	16.2
	57	0.5	16.0
	58	0.3	16.0
	59	0.2	15.5
	60	0.2	15.0
	61	0.2	15.0
11-Aug-89	1	8.2	23.9
	2	8.1	23.8
	3	7.9	23.8
	4	7.5	23.7
	5	6.6	23.6
	6	5.7	23.4
	7	5.9	23.2
	8	6.0	23.2
	9	5.4	23.1
	10	4.0	23.0
	11	3.2	22.9
	12	1.2	22.3
	13	0.0	21.5
	14	0.0	20.1
	15	0.0	19.2
	16	0.0	18.9
	17	0.0	18.2
	18	0.0	18.1
	19	0.0	17.4
	20	0.0	16.3
	21	0.0	15.0
	22	0.0	14.1
	23	0.0	13.3
	24	0.0	12.4
	25	0.0	11.3
	26	0.0	11.9
02-Oct-89	1	6.7	22.8
	2	6.0	22.5
	3	5.6	22.2
	4	5.6	22.2
	5	5.6	22.2
	6	5.6	22.2

Table A8. Continued....

DATE	DEPTH (m)	D.O. (mg/l)	TEMP. (C)
	7	5.5	22.3
	8	5.5	22.3
	9	5.3	22.2
	10	5.5	22.3
	11	5.0	22.2
	12	4.9	22.1
	13	4.1	22.0
	14	3.3	21.6
	15	2.9	21.4
	16	2.8	21.4
	17	3.1	21.4
	18	3.2	21.3
	19	2.6	21.1
	20	2.0	21.1
	21	2.2	21.1
23-Aug-90	1	10.8	29.8
	2	10.8	29.5
	3	10.8	29.5
	4	10.8	29.5
	5	8.9	28.3
	6	8.1	27.9
	7	7.4	27.5
	8	5.1	27.0
	9	4.5	26.8
	10	3.6	26.4
	11	2.8	26.1
	12	2.1	26.0
	13	2.0	25.9
	14	1.7	25.8
	15	1.0	25.5
	16	0.4	25.2
	17	0.2	24.9
	18	0.1	24.0
	19	0.1	23.2
	20	0.0	21.9

Table A?. Grand Lake alkalinity/hardness data from WQRL.

DATE	STATION[1]	ALKALINITY (mg/l as CaCO3)	HARDNESS (mg/l as CaCO3)
21-Jun-89	1S	122	168
	1B	118	170
	2Sa	88	114
	2Sb	86	116
	2Sc	86	120
	2Ba	100	132
	2Bb	100	136
	2Bc	98	140
	3S	86	110
	3B	98	134
	4S	72	108
	4B	90	124
21-Jul-89	1Sa	60	116
	1Sb	60	110
	1Sc	58	110
	1BA	60	106
	1BB	60	104
	1BC	60	106
	2S	110	146
	2B	96	144
	3S	134	120
	3B	110	136
	4S	86	104
	4B	100	136
10-Aug-89	1S	72	112
	1B	64	100
	2S	82	118
	2B	112	142
	3S	88	118
	3B	102	130
	4Sa	82	118
	4Sb	82	140
	4Sc	78	112
	4Ba	104	110
	4Bb	102	138
	4Bc	110	142

[1] Station ID's with lower case letters represent triplicates.

(Table A? continued)

07-Sep-89	1S	90	126
	1B	90	122
	2S	68	94
	2B	78	106
	3Sa	80	110
	3Sb	76	110
	3Sc	80	110
	3Ba	82	110
	3Bb	72	100
	3Bc	74	102
02-Oct-89	1S	124	160
	1B	166	166
	2S	82	104
	2B	86	146
	3S	74	110
	3B	82	114
	4Sa	76	106
	4Sb	80	112
	4Sc	76	118
	4Ba	74	106
	4Bb	80	114
	4Bc	82	118

Table A?. Grand Lake anion data from WQRL.

DATE	STATION[2]	Cl- mg/l	NO2 mg/l	NO3- mg/l	(o-P) mg/l	(TOT-P) mg/l	SO4-2 mg/l
21-Jul-88	1Sa	13.1	<0.010	0.255	0.051	--	66.6
	1Ba	10.8	<0.010	0.069	0.080	--	63.4
	1Sb	12.8	<0.010	0.150	0.053	--	65.6
	1Bb	15.9	<0.010	0.070	0.092	--	57.4
	1C	12.6	<0.010	0.049	0.050	--	73.6
	1D	12.2	<0.010	<0.010	0.050	--	64.9
	1E	12.6	<0.010	<0.010	0.025	--	74.3
	1F	10.6	<0.010	<0.010	0.060	--	54.4
	1G		--	<0.010	0.075	--	--
10-Aug-88	pH = 7.	6.0	--	0.030	<0.005	--	123.0
10-Aug-88	pH = 5.	6.3	--	0.034	<0.005	--	132.0
18-Aug-88	NE NEOS	10.6	--	0.004	0.539	--	28.7
	SP-2 SP	19.2	--	3.451	0.291	--	46.4
	EU ELK	8.3	--	1.497	0.252	--	3.9
	HC8 HON	--	--	5.008	4.363	--	18.5
	HC9 HON	9.2	--	2.691	--	--	2.8
	1S	10.2	--	--	0.538	--	31.2
	1B	10.1	--	0.211	0.574	--	30.5
	AS	11.6	--	0.000	0.393	--	30.4
	AB	10.4	--	2.691	0.599	--	29.1
	GRDA 2S	8.9	--	--	0.302	--	28.6
	GRDA 2B	7.3	0.004	0.211	0.454	--	19.6
	GRDA 3S	7.9	0.001	0.000	0.287	--	26.1
	GRDA 3B	7.0	--	2.691	0.476	--	21.2
	GRDA 4S	7.7	--	--	--	--	26.0
	GRDA 4B	6.8	--	--	--	--	22.8
06-Jun-89	1S	98.8	<0.010	0.513	<0.050	0.429	38.3
	1B	--	<0.010	0.522	<0.050	0.202	40.2
	2S	77.5	<0.010	0.669	<0.050	0.204	24.0
	2B	86.6	<0.010	0.758	<0.050	0.149	26.6
	3Sa	88.1	<0.010	0.417	<0.050	0.116	26.2
	3Sb	88.3	<0.010	0.409	<0.050	0.038	26.2
	3B	87.0	<0.010	0.834	<0.050	0.069	21.2
	4S	80.5	<0.010	0.503	<0.050	<0.005	26.8
	4B	88.1	<0.010	0.851	<0.050	0.073	27.8
21-Jun-89	1S	12.8	<0.050	0.077	<0.050	0.441	53.6
	1B	13.0	<0.050	0.270	<0.050	0.478	54.6
	2Sa	7.7	<0.050	0.433	<0.050	0.044	31.1

[2] Lower case letters represent replicate samples.

(Table A? continued)

	2Sb	7.2	<0.050	0.416	<0.050	0.079	30.7
	2Sc	7.4	<0.050	0.423	<0.050	0.104	30.8
	2Ba	7.9	<0.050	0.507	<0.050	0.155	32.3
	2Bb	7.0	<0.050	0.504	<0.050	0.167	32.2
	2Bc	6.6	<0.050	0.507	<0.050	0.177	32.2
	3S	7.4	<0.050	0.318	<0.050	0.032	32.9
	3B	7.7	<0.050	0.962	<0.050	0.018	34.2
	4S	7.4	<0.050	0.412	<0.050	0.061	34.1
	4B	7.4	<0.050	1.030	<0.050	0.030	35.2
21-Jul-89	1Sa	--	--	--	--	0.566	--
	1Sb	--	--	--	--	0.210	--
	1Sc	--	--	--	--	0.392	--
	1B	--	--	--	--	0.491	--
	2S	--	--	--	--	0.098	--
	2B	--	--	--	--	0.423	--
	3S	--	--	--	--	0.030	--
	3B	--	--	--	--	0.226	--
	4S	--	--	--	--	0.001	--
	4B	--	--	--	--	0.054	--
10-Aug-89	1S	9.2	<0.050	0.195	<0.050	0.298	38.7
	1B	11.0	<0.050	0.266	0.373	0.236	45.2
	2S	9.7	<0.050	0.233	<0.050	0.035	36.2
	2B	--	<0.050	--	--	0.913	--
	3S	8.2	<0.050	<0.050	<0.050	<0.005	31.3
	3B	6.5	<0.050	<0.050	0.119	0.411	23.2
	4Sa	8.7	<0.050	<0.050	<0.050	<0.005	31.6
	4Sb	3.4	<0.050	<0.050	<0.050	0.165	29.9
	4Sc	11.0	<0.050	<0.050	<0.050	<0.005	35.8
	4Ba	6.9	<0.050	<0.050	<0.050	0.140	26.2
	4Bb	10.3	<0.050	<0.050	<0.050	<0.005	34.5
	4Bc	9.9	<0.050	<0.050	<0.050	0.154	34.6
05-Sep-89	1S	--	<0.050	--	--	0.403	--
	1B	--	<0.050	--	--	0.604	--
	2S	--	<0.050	--	--	0.164	--
	2B	--	<0.050	--	--	0.331	--
	3Sa	--	<0.050	--	--	0.027	--
	3Sb	--	<0.050	--	--	0.108	--
	3Sc	--	<0.050	--	--	0.029	--
	3Ba	--	<0.050	--	--	0.132	--
	3Bb	--	<0.050	--	--	0.137	--
	3Bc	--	<0.050	--	--	0.100	--
	4S	--	<0.050	--	--	--	--
	4B	--	<0.050	--	--	--	--
02-Oct-89	1S	10.2	<0.050	0.937	<0.050	0.170	40.1
	1B	8.9	<0.050	0.607	<0.050	0.687	40.0
	2S	8.3	<0.050	0.832	<0.050	0.178	24.5

(Table A? continued)

NO3

	2B	8.7	<0.050	0.808	<0.050	0.410	27.2
	3S	8.7	<0.050	0.619	0.090	0.015	26.3
	3B	8.1	<0.050	0.413	<0.050	0.198	25.2
	4Sa	8.8	<0.050	0.500	<0.050	0.011	29.9
	4Sb	9.1	<0.050	0.275	<0.050	0.119	29.1
	4Sc	9.0	<0.050	0.300	<0.050	0.066	28.9
	4Ba	8.2	<0.050	0.930	<0.050	0.158	27.7
	4Bb	8.6	<0.050	0.532	0.060	0.199	26.2
	4Bc	8.5	<0.050	0.572	<0.050	0.178	25.2
10-Jul-90	1S	9.9	<0.050	0.990	<0.050	0.217	31.6
	1B	8.8	<0.050	0.980	0.060	0.262	30.7
	2S	7.2	<0.050	0.410	0.050	0.117	29.4
	2B	6.4	<0.050	0.390	0.050	0.109	11.7
	T2A	7.0	<0.050	0.330	0.060	0.132	26.3
	T2B	7.2	<0.050	0.350	0.050	0.124	27.3
	T2C	7.0	<0.050	0.350	0.080	0.111	27.1
	3S	6.7	<0.050	0.360	<0.050	0.096	26.4
	3B	6.2	<0.050	0.570	0.070	0.182	18.4
	T3A	6.6	<0.050	0.340	0.040	0.078	25.6
	T3B	6.7	<0.050	0.380	<0.050	0.102	25.7
	ERBS	6.9	<0.050	0.080	<0.050	0.098	22.8
	NER1	7.6	<0.050	0.600	0.070	0.137	27.4
	NER2	7.4	<0.050	0.570	0.090	0.189	27.5
	NER3	7.5	<0.050	0.570	0.100	0.184	27.2
	ER1	7.0	<0.050	0.380	0.080	0.130	26.1
	ER2	7.1	<0.050	0.430	0.040	0.154	26.1
	ER3	7.1	<0.050	0.500	0.050	0.150	26.4
23-Aug-90	1SA	11.5	<0.050	0.736	<0.010	0.144	34.4
	1SB	11.8	<0.050	0.739	<0.010	0.174	34.3
	1SC	11.8	<0.050	0.763	<0.010	0.193	34.1
	1BA	9.8	<0.050	0.829	<0.010	<0.005	30.2
	1BB	9.5	<0.050	0.784	<0.010	0.160	30.6
	1BC	9.8	<0.050	0.766	0.014	0.167	30.4
	2S	6.8	<0.050	<0.020	<0.010	<0.005	27.7
	2B	6.0	<0.050	<0.020	0.078	0.045	20.6
	3SA	5.4	<0.050	<0.020	<0.010	<0.005	26.3
	3SB	5.4	<0.050	<0.020	<0.010	0.005	26.3
	3SC	5.3	<0.050	<0.020	<0.010	<0.005	25.6
	3BA	4.9	<0.050	0.031	0.041	0.137	21.8
	3BB	4.9	<0.050	0.039	0.034	0.101	21.8
	3BC	4.9	<0.050	0.041	0.061	0.035	21.8
	4S	5.0	<0.050	0.056	<0.010	<0.005	26.0
	4B	4.9	<0.050	0.364	<0.010	0.019	24.6

Table A?. Grand Lake cation analysis (data from WQRL).

DATE	STATION	Na+ mg/L	NH4+ mg/L	K+ mg/L	Mg++ mg/L	Ca++ mg/L
06-Jun-89	1S	27.8	<0.10	16.16	13.28	66.73
	1B	62.0	0.93	25.90	11.71	61.28
	2S	61.9	1.10	25.68	7.76	48.31
	2B	27.6	<0.10	15.77	7.51	57.38
	3Sa	60.9	1.01	25.00	7.23	49.61
	3Sb	52.2	0.60	22.01	7.53	53.60
	3B	---	---	---	---	---
	4S	36.5	0.10	17.46	7.68	62.57
	4B	36.5	0.10	17.46	7.68	62.57
21-Jun-89	1S	14.6	<1.00	9.37	12.75	51.51
	1B	---	19.54	23.37	15.62	54.55
	2Sa	---	14.38	16.42	7.10	40.21
	2Sb	---	9.77	16.06	6.79	41.87
	2Sc	---	10.42	24.55	7.07	39.65
	2Ba	---	7.49	14.49	6.97	47.15
	2Bb	---	<1.00	7.94	7.26	50.20
	2Bc	15.4	<1.00	8.78	12.31	53.84
	3S	8.6	<1.00	10.32	5.80	40.91
	3B	1.4	<1.00	7.96	5.83	48.77
	4S	9.9	<1.00	11.27	7.16	39.95
	4B	18.4	<1.00	16.90	7.84	54.30
21-Jul-89	1Sa	---	8.72	19.88	9.78	25.49
	1Sb	12.8	0.99	3.76	----	----
	1Sc	---	----	12.97	10.27	30.63
	1Ba	---	2.04	13.45	10.72	34.32
	1Bb	---	2.83	13.03	10.52	34.36
	1Bc	30.0	3.24	11.47	11.32	33.31
	2S	2.9	<1.00	8.37	12.10	41.51
	2B	28.9	1.30	9.63	9.47	45.11
	3S	1.7	<1.00	6.94	8.89	47.83
	3B	---	----	----	----	----
	4S	6.1	<1.00	8.95	9.40	33.51
	4B	29.7	<1.00	30.92	12.97	43.89
10-Aug-89	1S	17.7	<1.00	41.06	6.33	30.81
	1B	16.8	<1.00	35.64	3.98	---
	2S	27.4	11.30	19.96	7.74	42.77
	2B	---	---	---	---	---
	3S	---	---	---	---	---
	3B	---	---	---	---	---
	4Sa	---	---	---	---	---
	4Sb	---	---	---	---	---
	4Sc	---	---	---	---	---
	4Ba	---	---	---	---	---

4Bb	---	---	---	---	---

(Table A? continued)

	4Bc	---	---	---	---	---
05-Sep-89	1S	---	---	---	---	---
	1B	11.1	<1.00	15.93	9.61	50.01
	2S	11.1	<1.00	11.70	6.78	39.29
	2B	11.3	<1.00	14.15	8.06	45.11
	3Sa	12.6	<1.00	12.25	7.66	44.85
	3Sb	12.6	<1.00	9.66	7.42	44.29
	3Sc	11.6	<1.00	12.26	7.72	43.26
	3Ba	10.6	<1.00	13.34	6.82	26.67
	3Bb	10.9	<1.00	15.21	6.60	37.78
	3Bc	10.3	<1.00	11.97	6.78	38.63
	4S	---	<1.00	---	---	---
	4B	---	<1.00	---	---	---
02-Oct-89	1S	14.1	<1.00	19.79	10.30	61.77
	1B	13.6	<1.00	24.94	10.86	74.68
	2S	10.7	<1.00	18.28	7.11	37.76
	2B	12.6	<1.00	23.79	8.80	47.83
	3S	11.7	<1.00	17.06	7.02	37.66
	3B	10.2	<1.00	21.89	7.08	43.20
	4Sa	11.0	<1.00	17.95	6.73	40.21
	4Sb	11.4	<1.00	18.21	6.88	43.29
	4Sc	12.6	<1.00	20.35	7.39	43.65
	4Ba	12.6	<1.00	24.43	7.17	38.54
	4Bb	12.5	<1.00	23.36	7.48	45.21
	4Bc	11.4	<1.00	19.01	7.12	41.72
10-Jul-90	1S	8.8	<1.00	3.91	7.87	59.54
	1B	7.6	<1.00	3.30	7.92	60.64
	2S	7.3	<1.00	2.74	6.76	38.03
	2B	3.4	<1.00	1.85	5.64	45.13
	T2A	7.4	<1.00	2.21	7.61	59.31
	T2B	8.6	<1.00	3.52	7.84	52.64
	T2C	6.8	<1.00	3.05	7.52	43.32
	3S	7.0	<1.00	2.31	6.93	34.36
	3B	5.4	1.37	4.67	6.33	44.45
	T3A	7.6	<1.00	2.85	7.25	39.56
	T3B	8.6	<1.00	3.73	6.35	46.09
	ERBS	11.6	<1.00	5.27	7.74	46.78
	NER1	10.0	<1.00	4.56	9.51	52.96
	NER2	8.4	<1.00	3.53	7.75	57.08
	NER3	9.2	<1.00	3.87	9.54	63.15
	ER1	8.1	<1.00	3.40	8.33	51.13
	ER2	8.0	<1.00	3.39	7.08	54.72
	ER3	7.9	1.42	3.21	7.97	50.53

1. Depth increments for 21 Jun 89 at all 4 stations are feet.

2. Depth increments for 21 Jun 89 at all 4 stations are feet.

NPID	STATE	CNTN	MADI	FTYP	FNMS
AR0020273	ARKANSAS	BENTON	MAJOR	MUNICIPAL	SILOAM SPRINGS, CITY OF
AR0023833	ARKANSAS	BENTON	MINOR	MUNICIPAL	GRAVETTE, CITY OF
AR0034258	ARKANSAS	BENTON	MINOR	INDUSTRIAL	ECCO SERVICES INC-BELLA VISTA
AR0036480	ARKANSAS	BENTON	MINOR	MUNICIPAL	SULPHUR SPRINGS, CITY OF
AR0041904	ARKANSAS	BENTON	MINOR	INDUSTRIAL	FIRST BRNADS CORP-HOME & AUTO
KS0000469	KANSAS	LYON	MINOR	INDUSTRIAL	AT&SF RR EMPORIA
KS0000477	KANSAS	NEOSHO	MINOR	INDUSTRIAL	AT&SF RR CHANUTE
KS0000493	KANSAS	CHEROKEE	MINOR	INDUSTRIAL	THERMEX ENERGY CORP.
KS0000612	KANSAS	LABETTE	MINOR	INDUSTRIAL	KANSAS GAS & ELECT CO PARSONS
KS0000701	KANSAS	LYON	MINOR	INDUSTRIAL	MONARCH CEMENT CO.
KS0000736	KANSAS	ALLEN	MINOR	INDUSTRIAL	IOLA CITY OF WTP
KS0000795	KANSAS	COFFEY	MINOR	INDUSTRIAL	LEROY CITY OF WTP
KS0000817	KANSAS	LYON	MAJOR	INDUSTRIAL	IBP,INCOR
KS0001180	KANSAS	LABETTE	MINOR	INDUSTRIAL	ALTAMONT CITY OF WTP
KS0001201	KANSAS	NEOSHO	MINOR	INDUSTRIAL	ASH GROVE CEMENT CO CHANUTE P
KS0001279	KANSAS	NEOSHO	MINOR	INDUSTRIAL	ERIE CITY OF WTP
KS0001295	KANSAS	CHASE	MINOR	INDUSTRIAL	STRONG CITY CITY OF WTP
KS0001309	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	KC SO RR CO PITTSBURG
KS0001325	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	DICKEY CLAY MFG CO PITTSBURG
KS0001350	KANSAS	MARION	MINOR	INDUSTRIAL	ASSOCIATED MILK PROD. INC.
KS0021393	KANSAS	CRAWFORD	MINOR	MUNICIPAL	MCCUNE CITY OF STP
KS0022551	KANSAS	CRAWFORD	MINOR	MUNICIPAL	GIRARD CITY OF WWTP
KS0022632	KANSAS	ALLEN	MINOR	MUNICIPAL	HUMBOLDT WWTF
KS0024732	KANSAS	WOODSON	MINOR	MUNICIPAL	YATES CENTER CITY OF STP
KS0024767	KANSAS	COFFEY	MINOR	MUNICIPAL	LEBO CITY OF STP
KS0025526	KANSAS	NEOSHO	MINOR	MUNICIPAL	STARK CITY OF WWTP
KS0025682	KANSAS	LYON	MINOR	MUNICIPAL	HARTFORD CITY OF STP
KS0026131	KANSAS	CRAWFORD	MINOR	MUNICIPAL	FRONTENAC CITY OF WWTP
KS0026221	KANSAS	COFFEY	MINOR	MUNICIPAL	BURLINGTON CITY OF STP
KS0026417	KANSAS	MARION	MINOR	MUNICIPAL	LEHIGH CITY OF STP
KS0027898	KANSAS	MORRIS	MINOR	MUNICIPAL	COUNCIL GROVE CITY OF STP
KS0028533	KANSAS	CRAWFORD	MINOR	MUNICIPAL	HEPLER CITY OF STP
KS0029360	KANSAS	LABETTE	MAJOR	FEDERAL	US ARMY-KANSAS ARMY AMMUNITION
KS0030589	KANSAS	MARION	MINOR	MUNICIPAL	HILLSBORO CITY OF
KS0030813	KANSAS	COFFEY	MINOR	MUNICIPAL	LEROY CITY OF STP
KS0031135	KANSAS	LABETTE	MINOR	MUNICIPAL	CHETOPA CITY OF WWTP
KS0031178	KANSAS	CHASE	MINOR	MUNICIPAL	STRONG CITY CITY OF WWTP
KS0031445	KANSAS	CHEROKEE	MINOR	MUNICIPAL	COLUMBUS CITY OF STP
KS0032123	KANSAS	ALLEN	MAJOR	MUNICIPAL	IOLA CITY OF STP
KS0036722	KANSAS	LABETTE	MAJOR	MUNICIPAL	PARSONS WATER & SEWER DEPT
KS0037672	KANSAS	WOODSON	MINOR	INDUSTRIAL	BLACKJACK CATTLE CO INC FEEDL
KS0038652	KANSAS	NEOSHO	MINOR	MUNICIPAL	CHANUTE CITY OF WWTP
KS0038954	KANSAS	CRAWFORD	MAJOR	MUNICIPAL	PITTSBURG CITY OF MUN WWTP
KS0041572	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	DICKEY W S CLAY MFG CO
KS0041726	KANSAS	LABETTE	MINOR	INDUSTRIAL	NATIONAL FARMS FEEDLOTS
KS0045918	KANSAS	LABETTE	MINOR	MUNICIPAL	ALTAMONT CITY OF STP
KS0045926	KANSAS	CRAWFORD	MINOR	MUNICIPAL	ARMA CITY OF STP
KS0045934	KANSAS	CHEROKEE	MINOR	MUNICIPAL	BAXTER SPRINGS CITY OF STP
KS0045977	KANSAS	NEOSHO	MINOR	MUNICIPAL	ERIE CITY OF WWTP
KS0045993	KANSAS	COFFEY	MINOR	MUNICIPAL	GRIDLEY CITY OF STP

NPID	STATE	CNTN	MADI	FTYP	FNMS
KS0046043	KANSAS	NEOSHO	MINOR	MUNICIPAL	ST PAUL CITY OF STP
KS0046728	KANSAS	LYON	MAJOR	MUNICIPAL	EMPORIA, CITY OF
KS0047406	KANSAS	LYON	MINOR	MUNICIPAL	AMERICUS CITY OF STP
KS0047554	KANSAS	LABETTE	MINOR	MUNICIPAL	OSWEGO CITY OF STP
KS0047571	KANSAS	LYON	MINOR	MUNICIPAL	OLPE CITY OF STP
KS0048135	KANSAS	CHEROKEE	MINOR	MUNICIPAL	GALENA CITY OF STP EXEMPT
KS0051268	KANSAS	LYON	MINOR	INDUSTRIAL	FLINT HILLS FEEDLOT INC
KS0051659	KANSAS	WABAUNSEE	MINOR	MUNICIPAL	ALTA VISTA CITY OF STP
KS0051675	KANSAS	MORRIS	MINOR	MUNICIPAL	DWIGHT CITY OF STP
KS0051691	KANSAS	MARION	MINOR	MUNICIPAL	MARION CITY OF STP
KS0051705	KANSAS	MARION	MINOR	MUNICIPAL	PEABODY WWTD
KS0053660	KANSAS	CHASE	MINOR	INDUSTRIAL	KANSAS TURNPIKE AUTHORITY MAT
KS0053678	KANSAS	LYON	MINOR	INDUSTRIAL	KANSAS TURNPIKE AUTHORITY EMP
KS0079057	KANSAS	COFFEY	MAJOR	INDUSTRIAL	WOLF CREEK NUCLEAER OPERATING
KS0079146	KANSAS	CHEROKEE	MINOR	MUNICIPAL	WEIR CITY OF WWTP
KS0079472	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	THE CLEMENS COAL CO MINE #22
KS0079481	KANSAS	CHEROKEE	MINOR	INDUSTRIAL	WILKINSONS INC
KS0079529	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	ALTERNATE FULES, CROWEBURG #1
KS0079766	KANSAS	LABETTE	MINOR	INDUSTRIAL	CHETOPA MINE
KS0079812	KANSAS	CHEROKEE	MAJOR	INDUSTRIAL	EMPIRE DIST. ELECTRIC PLT-RIVE
KS0079880	KANSAS	NEOSHO	MINOR	INDUSTRIAL	CHANUTE CITY OF MUNIC PWPL
KS0079952	KANSAS	ALLEN	MINOR	MUNICIPAL	SAVONBURG CITY OF WWTP
KS0080225	KANSAS	CRAWFORD	MINOR	OTHER	MARAD EXPLORATION CORP
KS0080349	KANSAS	LABETTE	MINOR	INDUSTRIAL	FUEL DYNAMICS INC TIPPLE FACIL
KS0080357	KANSAS	CHEROKEE	MINOR	MUNICIPAL	SCAMMON WASTEWATER TREATMENT F
KS0080551	KANSAS	NEOSHO	MINOR	MUNICIPAL	TULAKES HOUSING DEVELOPMENT, I
KS0080837	KANSAS	NEOSHO	MAJOR	MUNICIPAL	CHANUTE WWTP (NEW PLANT)
KS0080845	KANSAS	LYON	MINOR	INDUSTRIAL	BROWNING MOBILE HOME PARK WWTP
KS0080861	KANSAS	CHEROKEE	MINOR	MUNICIPAL	WEST MINERAL CITY OF WWTP
KS0080900	KANSAS	LABETTE	MINOR	MUNICIPAL	BARTLETT CITY OF WWTP
KS0081230	KANSAS	CRAWFORD	MINOR	MUNICIPAL	CHEROKEE WWTP
KS0081345	KANSAS	CHEROKEE	MINOR	INDUSTRIAL	O'MALLEY RAMP PROJECT
KS0081400	KANSAS	LABETTE	MINOR	INDUSTRIAL	ALPHA 1 MINE (OSWEGO COAL CO)
KS0081566	KANSAS	MORRIS	MINOR	INDUSTRIAL	WHITE MEMORIAL CAMP WWTP
KS0081639	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	PITTSBURG MINE
KS0081698	KANSAS	CHEROKEE	MINOR	MUNICIPAL	TREECE WWTP
KS0082473	KANSAS	ALLEN	MINOR	INDUSTRIAL	OSWEGO COAL CO-BARTLETT MINE
KS0082597	KANSAS	NEOSHO	MINOR	INDUSTRIAL	CHANUTE, CITY OF POWER PLNT 3
KS0082694	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	MINE NO. 2
KS0083577	KANSAS	COFFEY	MINOR	INDUSTRIAL	NATIONAL MARKETING TRUCK STOP
KS0084077	KANSAS	CHEROKEE	MINOR	INDUSTRIAL	U.S.D. #404-RIVERTON SCHOOL
KS0084174	KANSAS	NEOSHO	MINOR	MUNICIPAL	ST. PAUL CITY OF MUNIC WWTP
KS0084484	KANSAS	LYON	MINOR	INDUSTRIAL	MODINE MANUFACTURING COMPANY
KS0085201	KANSAS	ALLEN	MINOR	MUNICIPAL	ALLEN COUNTY SEWER DIST 1 WWTP
KS0085588	KANSAS	MCPHERSON	MINOR	INDUSTRIAL	SHERWIN UNRUH
KS0115479	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	MIDWEST MINERALS INC QUARRY 2
KS0115487	KANSAS	LABETTE	MINOR	INDUSTRIAL	MIDWEST MINERALS INC QUARRY 2
KS0115525	KANSAS	LABETTE	MINOR	INDUSTRIAL	MIDWEST MINERALS INC QUARRY 3
KS0115584	KANSAS	LYON	MINOR	INDUSTRIAL	COUNTRY PARK MHC WWTP
KS0115606	KANSAS	LYON	MINOR	INDUSTRIAL	WHEAT RANCH FEEDLOT

NPID	STATE	CNTN	MADI	FTYP	FNMS
KS0115762	KANSAS	MARION	MINOR	INDUSTRIAL	HALLETT CONSTRUCTION CO MARION
KS0115819	KANSAS	NEOSHO	MINOR	INDUSTRIAL	TRIPLE R RANCH FEEDLOT
KS0115827	KANSAS	WOODSON	MINOR	INDUSTRIAL	PRINGLE PRE-CONDITION FEEDLOT
KS0115835	KANSAS	CHASE	MINOR	INDUSTRIAL	TALKINGTON EUGENE FEEDLOT
KS0115851	KANSAS	LYON	MINOR	INDUSTRIAL	BRAUM DAIRY FARM
KS0116122	KANSAS	ANDERSON	MINOR	MUNICIPAL	COLONY MUN WWTF
KS0116327	KANSAS	CHEROKEE	MINOR	MUNICIPAL	CHEROKEE COUNTY SEWER DIST 1 W
KS0116378	KANSAS	MORRIS	MINOR	INDUSTRIAL	F & R SWINE INC FEEDLOT
KS0116491	KANSAS	MORRIS	MINOR	MUNICIPAL	WHITE CITY CITY OF STP
KS0117021	KANSAS	LYON	MINOR	MUNICIPAL	NEOSHO RAPIDS CITY OF WWTP
KS0117129	KANSAS	LABETTE	MINOR	INDUSTRIAL	MISSOURI-KANSAS-TEXAS RAILROAD
KS0117412	KANSAS	MORRIS	MINOR	INDUSTRIAL	HAMM N R QUARRY CLARK QUARRY 2
KS0117846	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	PURITAN-BENNETT CORP-MILITARY
KS0117871	KANSAS	LYON	MINOR	INDUSTRIAL	THUNDERBIRD ESTATES
KS0118354	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	WHISPERING PINES MOBILE HOME P
KS0118508	KANSAS	MORRIS	MINOR	INDUSTRIAL	PIONEER PORK
KS0118516	KANSAS	COFFEY	MINOR	INDUSTRIAL	MARTIN MARIETTA CORP WUEREFELE
KS0118621	KANSAS	CHEROKEE	MINOR	INDUSTRIAL	BAXTER SPRINGS CITY OF WTP
KS0118681	KANSAS	LYON	MINOR	INDUSTRIAL	EMPORIA CITY OF WTP
KS0118737	KANSAS	ALLEN	MINOR	INDUSTRIAL	HUMBOLDT CITY OF WTP
KS0118745	KANSAS	LYON	MINOR	INDUSTRIAL	HARTFORD CITY OF WTP
KS0118931	KANSAS	WOODSON	MINOR	INDUSTRIAL	NEOSHO FALLS RWD 1
KS0118958	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	PITTSBURG CITY OF WTP
KS0118966	KANSAS	WOODSON	MINOR	INDUSTRIAL	YATES CENTER CITY OF WTP
KS0118991	KANSAS	NEOSHO	MINOR	INDUSTRIAL	ST PAUL CITY OF WTP
KS0119130	KANSAS	LABETTE	MINOR	INDUSTRIAL	PARSONS CITY OF WTP
KS0119164	KANSAS	CHEROKEE	MINOR	INDUSTRIAL	COLUMBUS CITY OF WTP
KS0119229	KANSAS	NEOSHO	MINOR	INDUSTRIAL	ERIE CITY OF RWD NO 02 WTP
KS0119237	KANSAS	LYON	MINOR	INDUSTRIAL	AMERICUS WTP RWD NO 01
KS0119261	KANSAS	CRAWFORD	MINOR	INDUSTRIAL	ARMA CITY OF WTP
KS0119270	KANSAS	LABETTE	MINOR	INDUSTRIAL	ROBISON JOSEPH J. FEEDLOT
KS0119431	KANSAS	LYON	MINOR	INDUSTRIAL	THUNDERBIRD ESTATES WTP
KS0119458	KANSAS	CHASE	MINOR	INDUSTRIAL	COTTONWOOD FALLS CITY OF WTP
KS0119491	KANSAS	CHASE	MINOR	INDUSTRIAL	ELMDALE CITY OF WWTP
KS0119521	KANSAS	MARION	MINOR	INDUSTRIAL	MARION CITY OF WTP
KS0119806	KANSAS	LYON	MINOR	INDUSTRIAL	FLATROCK MOBILE HOME PARK
MO0002313	MISSOURI	JASPER	MINOR	INDUSTRIAL	TAMKO ASPHALT PRODUCTS
MO0002348	MISSOURI	JASPER	MAJOR	INDUSTRIAL	EAGLE-PICHER INDUS. INC.
MO0002356	MISSOURI	LAWRENCE	MAJOR	INDUSTRIAL	SYNTEX AGRIBUSINESS
MO0002364	MISSOURI	JASPER	MINOR	INDUSTRIAL	EMPIRE MINE
MO0002372	MISSOURI	NEWTON	MINOR	FEDERAL	NEOSHO NATL FISH HATCHERY
MO0002381	MISSOURI	JASPER	MINOR	INDUSTRIAL	CMC, INC.
MO0002402	MISSOURI	JASPER	MAJOR	INDUSTRIAL	IRECO INC.
MO0002411	MISSOURI	JASPER	MAJOR	INDUSTRIAL	VICKERS, INC.
MO0002429	MISSOURI	JASPER	MINOR	INDUSTRIAL	W.R. GRACE & CO.
MO0002437	MISSOURI	LAWRENCE	MINOR	INDUSTRIAL	MID-AM DAIRY
MO0002453	MISSOURI	JASPER	MAJOR	INDUSTRIAL	ATLAS POWDER CO.
MO0002470	MISSOURI	JASPER	MINOR	INDUSTRIAL	INTERNATIONAL MULTIFOODS
MO0002500	MISSOURI	MCDONALD	MINOR	INDUSTRIAL	NOEL WATER CO,HUDSON FOOD
MO0002518	MISSOURI	NEWTON	MINOR	INDUSTRIAL	TELEDYNE NEOSHO

NPID	STATE	CNTN	MADI	FTYP	FNMS
MO0004073	MISSOURI	JASPER	MINOR	INDUSTRIAL	INDEPENDENT ASPHALT CO.
MO0021440	MISSOURI	BARRY	MAJOR	MUNICIPAL	MONETT
MO0022381	MISSOURI	LAWRENCE	MAJOR	MUNICIPAL	MOUNT VERNON
MO0023159	MISSOURI	LAWRENCE	MINOR	MUNICIPAL	MARIONVILLE
MO0023256	MISSOURI	JASPER	MINOR	MUNICIPAL	JOPLIN, SHOAL CR.
MO0023264	MISSOURI	JASPER	MAJOR	MUNICIPAL	JOPLIN, LONE ELM
MO0025186	MISSOURI	JASPER	MINOR	MUNICIPAL	CARL JUNCTION
MO0025801	MISSOURI	MCDONALD	MINOR	MUNICIPAL	ANDERSON
MO0028657	MISSOURI	JASPER	MINOR	MUNICIPAL	SARCOXIE
MO0031658	MISSOURI	BARTON	MINOR	MUNICIPAL	GOLDEN CITY
MO0034410	MISSOURI	BARTON	MINOR	INDUSTRIAL	BLUE TOP MOTEL AND CAFE
MO0035548	MISSOURI	JASPER	MINOR	INDUSTRIAL	I-44 REST STOP
MO0036757	MISSOURI	LAWRENCE	MAJOR	MUNICIPAL	AURORA
MO0036765	MISSOURI	MCDONALD	MINOR	MUNICIPAL	SOUTH WEST CITY
MO0036773	MISSOURI	MCDONALD	MAJOR	INDUSTRIAL	SIMMONDS INDUSTRIES
MO0039136	MISSOURI	JASPER	MAJOR	MUNICIPAL	CARTHAGE
MO0039926	MISSOURI	NEWTON	MAJOR	MUNICIPAL	NEOSHO, CROWDER
MO0040185	MISSOURI	JASPER	MAJOR	MUNICIPAL	WEBB CITY, CENTER CREEK
MO0040193	MISSOURI	JASPER	MINOR	MUNICIPAL	CARTERVILLE
MO0041149	MISSOURI	LAWRENCE	MINOR	MUNICIPAL	MILLER S.
MO0042013	MISSOURI	NEWTON	MINOR	MUNICIPAL	DIAMOND, W.
MO0044172	MISSOURI	BARTON	MINOR	MUNICIPAL	LAMAR
MO0044202	MISSOURI	JASPER	MINOR	MUNICIPAL	JASPER
MO0044750	MISSOURI	JASPER	MINOR	INDUSTRIAL	JESSE'S TRUCK STOP
MO0045641	MISSOURI	JASPER	MINOR	INDUSTRIAL	SHADY LANE MOBILE HOME PK
MO0049948	MISSOURI	MCDONALD	MINOR	INDUSTRIAL	LANAGAN HOUSING AUTH.#1
MO0053627	MISSOURI	JASPER	MINOR	INDUSTRIAL	FARMERS CHEMICAL CO.
MO0053970	MISSOURI	JASPER	MINOR	INDUSTRIAL	COUNTRY ACRES MHP
MO0054101	MISSOURI	JASPER	MINOR	INDUSTRIAL	F.A.G. BEARING CO.
MO0054721	MISSOURI	MCDONALD	MINOR	MUNICIPAL	NOEL
MO0058327	MISSOURI	NEWTON	MINOR	MUNICIPAL	DIAMOND, E.
MO0082627	MISSOURI	JASPER	MINOR	INDUSTRIAL	SHERWOOD FOREST MHP
MO0082767	MISSOURI	JASPER	MINOR	INDUSTRIAL	CON-AGRA TURKEY COMPANY
MO0083411	MISSOURI	NEWTON	MINOR	INDUSTRIAL	UNION CARBIDE IND. GASES
MO0083917	MISSOURI	LAWRENCE	MINOR	INDUSTRIAL	FASTRIP #17 (NIC. FARMS)
MO0085821	MISSOURI	JASPER	MINOR	INDUSTRIAL	PRONTO SNACK PLAZA NO. 8
MO0088277	MISSOURI	JASPER	MINOR	INDUSTRIAL	LEGGETT & PLATT WIRE MILL
MO0089036	MISSOURI	JASPER	MINOR	MUNICIPAL	ALBA
MO0092525	MISSOURI	LAWRENCE	MINOR	MUNICIPAL	VERONA
MO0093998	MISSOURI	JASPER	MINOR	INDUSTRIAL	TAMKO ASPHALT
MO0095362	MISSOURI	JASPER	MINOR	INDUSTRIAL	EMPIRE, ASBURY PP
MO0096270	MISSOURI	BARTON	MINOR	INDUSTRIAL	ANGEL EST.& COURTESY CT.
MO0096679	MISSOURI	MCDONALD	MINOR	MUNICIPAL	PINEVILLE
MO0097080	MISSOURI	MCDONALD	MINOR	INDUSTRIAL	STEPHENSON'S CIDER MILL
MO0097446	MISSOURI	JASPER	MINOR	INDUSTRIAL	WINTER HAVEN MHP
MO0097829	MISSOURI	JASPER	MINOR	INDUSTRIAL	COLLEGE HEIGHTS CHRISTIAN SCH
MO0098272	MISSOURI	BARTON	MINOR	INDUSTRIAL	MINDEN ACRES
MO0098833	MISSOURI	JASPER	MINOR	INDUSTRIAL	GREEN ACRES MHP
MO0099155	MISSOURI	LAWRENCE	MINOR	MUNICIPAL	PIERCE CITY
MO0099309	MISSOURI	JASPER	MINOR	INDUSTRIAL	LOMA LINDA ESTATES SUBD

NPID	STATE	CNTN	MADI	FTYP	FNMS
MO0100251	MISSOURI	MCDONALD	MINOR	INDUSTRIAL	LANAGAN HOUSING AUTH.#2
MO0100421	MISSOURI	JASPER	MINOR	INDUSTRIAL	TWIN HILLS SUBDIVISION
MO0102253	MISSOURI	JASPER	MINOR	INDUSTRIAL	FIBREX INC.
MO0103349	MISSOURI	JASPER	MAJOR	MUNICIPAL	JOPLIN, TURKEY CREEK
MO0104469	MISSOURI	BARTON	MINOR	INDUSTRIAL	SUNPYRE MINING, INC.
MO0104884	MISSOURI	JASPER	MINOR	INDUSTRIAL	LAKE ENTRANCE ASSOC
MO0104906	MISSOURI	NEWTON	MAJOR	MUNICIPAL	NEOSHO, SHOAL CR/CROWDER
MO0105678	MISSOURI	JASPER	MINOR	INDUSTRIAL	THE PILLSBURY CO.
MO0106135	MISSOURI	MCDONALD	MINOR	INDUSTRIAL	GINGER BLUE RESORT
MO0106283	MISSOURI	JASPER	MINOR	INDUSTRIAL	JOPLIN TRANSPORT CENTER
MO0106381	MISSOURI	JASPER	MINOR	INDUSTRIAL	P&M, EMPIRE MINE
MO0106861	MISSOURI	LAWRENCE	MINOR	INDUSTRIAL	MOUNT VERNON PRODUCTS TER
MO0107107	MISSOURI	JASPER	MINOR	INDUSTRIAL	MELODY MHP
MO0107166	MISSOURI	JASPER	MINOR	INDUSTRIAL	FAIRVIEW GREENHOUSE, INC.
MO0107573	MISSOURI	LAWRENCE	MINOR	INDUSTRIAL	MO BAPT CHILDREN'S HOME
MO0107581	MISSOURI	NEWTON	MINOR	MUNICIPAL	GRANBY
MO0108677	MISSOURI	BARRY	MINOR	MUNICIPAL	SELIGMAN
MO0108731	MISSOURI	JASPER	MINOR	INDUSTRIAL	JOPLIN LANDFILL
MO0108766	MISSOURI	JASPER	MINOR	INDUSTRIAL	SAGINAW COMPRESSOR STATIO
MO0108782	MISSOURI	LAWRENCE	MINOR	INDUSTRIAL	TRUCK STOP OF AMERICA
MO0108871	MISSOURI	JASPER	MINOR	INDUSTRIAL	CARTHAGE DEMOLITION LANDF
MO0108952	MISSOURI	MCDONALD	MINOR	INDUSTRIAL	SIMMONS HATCHERY
MO0109274	MISSOURI	LAWRENCE	MINOR	INDUSTRIAL	FREISTATT
MO0109541	MISSOURI	JASPER	MINOR	INDUSTRIAL	INLAND PRODUCTS
MO0110272	MISSOURI	BARTON	MINOR	INDUSTRIAL	LAMAR LANDFILL
MO0110299	MISSOURI	JASPER	MINOR	INDUSTRIAL	MISSOURI-NEBRASKA EXPRESS
MO0110426	MISSOURI	NEWTON	MINOR	INDUSTRIAL	NEWTON-MCDONALD LANDFILL
MO0111023	MISSOURI	BARRY	MINOR	MUNICIPAL	SELIGMAN
MO0111309	MISSOURI	LAWRENCE	MINOR	INDUSTRIAL	SHELL, LAWRENCE STA.
MO0111317	MISSOURI	NEWTON	MINOR	INDUSTRIAL	SHELL, DIAMOND STA.
MO0111325	MISSOURI	JASPER	MINOR	INDUSTRIAL	INTERNATIONAL PAPER
MO0111741	MISSOURI	LAWRENCE	MINOR	INDUSTRIAL	T AND C DISPOSAL, INC.
MO0111791	MISSOURI	MCDONALD	MINOR	INDUSTRIAL	B & B SAND & GRAVEL INC.
MO0112046	MISSOURI	BARTON	MINOR	INDUSTRIAL	LAMAR SAN & DEMO LANDFILL
MO0112101	MISSOURI	NEWTON	MINOR	INDUSTRIAL	TALBOT INDUS INC PLANT II
MO0112119	MISSOURI	NEWTON	MINOR	INDUSTRIAL	TALBOT INDUS INC PLANT I
MO0112372	MISSOURI	LAWRENCE	MINOR	INDUSTRIAL	TRUCKSTOPS OF AMERICA
MO0112534	MISSOURI	MCDONALD	MINOR	MUNICIPAL	GOODMAN
MO0112631	MISSOURI	NEWTON	MINOR	MUNICIPAL	FAIRVIEW
OK0001040	OKLAHOMA	OTTAWA	MINOR	INDUSTRIAL	B F GOODRICH
OK0001261	OKLAHOMA	OTTAWA	MAJOR	INDUSTRIAL	EAGLE PICHER IND-OTTAWA
OK0020320	OKLAHOMA	OTTAWA	MINOR	MUNICIPAL	COMMERCE, CITY OF
OK0020656	OKLAHOMA	OTTAWA	MINOR	MUNICIPAL	AFTON PUBLIC WORKS AUTHORITY
OK0021172	OKLAHOMA	DELAWARE	MINOR	INDUSTRIAL	PORT DUNCAN #1
OK0021458	OKLAHOMA	DELAWARE	MINOR	INDUSTRIAL	SPINNAKER PT. HOMEOWNER'S ASS.
OK0021504	OKLAHOMA	OTTAWA	MINOR	MUNICIPAL	FAIRLAND PWA (LAGOON)
OK0028258	OKLAHOMA	OTTAWA	MINOR	MUNICIPAL	QUAPAW PUBLIC WORKS AUTHORITY
OK0028291	OKLAHOMA	OTTAWA	MINOR	MUNICIPAL	OTTAWA CO. RW&SD #1 (WYANDOTTE
OK0028886	OKLAHOMA	DELAWARE	MINOR	MUNICIPAL	GROVE MUNICIPAL SERVICES AUTHO
OK0030236	OKLAHOMA	OTTAWA	MINOR	MUNICIPAL	SENECA, CITY OF (MISSOURI)

NPID	STATE	CNTN	MADI	FTYP	FNMS
OK0031798	OKLAHOMA	OTTAWA	MAJOR	MUNICIPAL	MIAMI, CITY OF (MAIN STP-OUTFA
OK0031801	OKLAHOMA	OTTAWA	MINOR	MUNICIPAL	MIAMI, CITY OF/MIAMI UTILITIES
OK0031976	OKLAHOMA	DELAWARE	MINOR	MUNICIPAL	JAY, TOWN OF (UA)
OK0032263	OKLAHOMA	OTTAWA	MINOR	MUNICIPAL	PICHER, CITY OF
OK0034789	OKLAHOMA	OTTAWA	MINOR	INDUSTRIAL	PORT DUNCAN RESORT MARINA, LTD
OK0034835	OKLAHOMA	CRAIG	MINOR	INDUSTRIAL	GRAND POINT RESORT-VINITA
OK0037036	OKLAHOMA	DELAWARE	MINOR	MUNICIPAL	GROVE MUNICIPAL SVS AUTH-QUAIL
OK0037770	OKLAHOMA	DELAWARE	MINOR	INDUSTRIAL	HARBORS "IN" CORPORATION-DELAW
OK0037842	OKLAHOMA	DELAWARE	MINOR	INDUSTRIAL	PINE ISLAND R.V. RESORT, INC.
OK0037869	OKLAHOMA	DELAWARE	MINOR	INDUSTRIAL	COVES MASTER ASSN. INC., THE
OK0037915	OKLAHOMA	DELAWARE	MINOR	INDUSTRIAL	WHITE CHAPEL HOMEOWNERS ASSOC.
OK0037923	OKLAHOMA	DELAWARE	MINOR	INDUSTRIAL	HERITAGE POINT
OK0037991	OKLAHOMA	OTTAWA	MINOR	INDUSTRIAL	MAINSTAY & BEACON HILL HOMEOWN
OK0038041	OKLAHOMA	DELAWARE	MINOR	INDUSTRIAL	SILVER KEY CONDOS-GRAND LAKE
OK0038598	OKLAHOMA	OTTAWA	MINOR	INDUSTRIAL	U.S. METAL CONTAINER COMPANY-M
OK0038687	OKLAHOMA	OTTAWA	MINOR	INDUSTRIAL	T.J. CLAIBOURNE DBA ROGERS CAR
OK0038962	OKLAHOMA	OTTAWA	MINOR	MUNICIPAL	CARDIN, CITY OF
OK0039039	OKLAHOMA	CRAIG	MINOR	INDUSTRIAL	PELICAN POINT HOMEOWNERS ASSOC
OK0039098	OKLAHOMA	OTTAWA	MINOR	MUNICIPAL	SENECA-CAYUGA TRIBE
OK0039144	OKLAHOMA	OTTAWA	MINOR	INDUSTRIAL	HI POINT ESTATES HOMEOWNERS
OK0040142	OKLAHOMA	OTTAWA	MINOR	INDUSTRIAL	EAGLE PICHER IND-BO
OK0041009	OKLAHOMA	OTTAWA	MINOR	INDUSTRIAL	SHELL PIPELINE-GRAND LAKE
OK0041025	OKLAHOMA	DELAWARE	MINOR	INDUSTRIAL	HALLETT MATERIALS-KIRBY QUARRY

STATE	COUNT OF NPID's
ARKANSAS	5
KANSAS	131
MISSOURI	103
OKLAHOMA	34
TOTAL	273

STATE	COUNTY	MADI	Count of MADI
ARKANSAS	BENTON	MAJOR	1
ARKANSAS	BENTON	MINOR	4
KANSAS	ALLEN	MAJOR	1
KANSAS	ALLEN	MINOR	6
KANSAS	ANDERSON	MINOR	1
KANSAS	CHASE	MINOR	6
KANSAS	CHEROKEE	MAJOR	1
KANSAS	CHEROKEE	MINOR	14
KANSAS	COFFEY	MAJOR	1
KANSAS	COFFEY	MINOR	7
KANSAS	CRAWFORD	MAJOR	1
KANSAS	CRAWFORD	MINOR	19
KANSAS	LABETTE	MAJOR	2
KANSAS	LABETTE	MINOR	15
KANSAS	LYON	MAJOR	2
KANSAS	LYON	MINOR	19
KANSAS	MARION	MINOR	7
KANSAS	MCPHERSON	MINOR	1
KANSAS	MORRIS	MINOR	7
KANSAS	NEOSHO	MAJOR	1
KANSAS	NEOSHO	MINOR	14
KANSAS	WABAUNSEE	MINOR	1
KANSAS	WOODSON	MINOR	5
MISSOURI	BARRY	MAJOR	1
MISSOURI	BARRY	MINOR	2
MISSOURI	BARTON	MINOR	8
MISSOURI	JASPER	MAJOR	8
MISSOURI	JASPER	MINOR	42
MISSOURI	LAWRENCE	MAJOR	3
MISSOURI	LAWRENCE	MINOR	13
MISSOURI	MCDONALD	MAJOR	1
MISSOURI	MCDONALD	MINOR	12
MISSOURI	NEWTON	MAJOR	2
MISSOURI	NEWTON	MINOR	11
OKLAHOMA	CRAIG	MINOR	2
OKLAHOMA	DELAWARE	MINOR	12
OKLAHOMA	OTTAWA	MAJOR	2
OKLAHOMA	OTTAWA	MINOR	18

FTYP	Count of FTYP
FEDERAL	2
INDUSTRIAL	170
MUNICIPAL	100
OTHER	1
TOTAL	273

Npid	Average Design Flow (MGD)
AR0020273	DNP
AR0023833	0.56
AR0034258	00.2
AR0036480	DNP
AR0041904	DNP
KS0000469	DNP
KS0000477	DNP
KS0000493	DNP
KS0000612	DNP
KS0000701	DNP
KS0000736	DNP
KS0000795	DNP
KS0000817	3.0
KS0001180	DNP
KS0001201	DNP
KS0001279	DNP
KS0001295	DNP
KS0001309	DNP
KS0001325	DNP
KS0001350	DNP
KS0021393	DNP
KS0022551	DNP
KS0022632	0.250
KS0024732	DNP
KS0024767	DNP
KS0025526	DNP
KS0025682	DNP
KS0026131	DNP
KS0026221	DNP
KS0026417	DNP
KS0027898	DNP
KS0028533	DNP
KS0029360	30.0
KS0030589	DNP
KS0030813	DNP
KS0031135	DNP
KS0031178	DNP
KS0031445	DNP
KS0032123	3.0
KS0036722	3.5
KS0037672	DNP
KS0038652	DNP
KS0038954	6.0
KS0041572	DNP
KS0041726	DNP
KS0045918	DNP
KS0045926	DNP
KS0045934	DNP
KS0045977	DNP
KS0045993	DNP

NPID	Average Design Flow (MGD)
KS0046043	DNP
KS0046728	4.2
KS0047406	DNP
KS0047554	DNP
KS0047571	DNP
KS0048135	DNP
KS0051268	DNP
KS0051659	DNP
KS0051675	DNP
KS0051691	0.54
KS0051705	DNP
KS0053660	DNP
KS0053678	DNP
KS0079057	0.1
KS0079146	DNP
KS0079472	DNP
KS0079481	DNP
KS0079529	DNP
KS0079766	DNP
KS0079812	47.5
KS0079880	DNP
KS0079952	DNP
KS0080225	DNP
KS0080349	DNP
KS0080357	DNP
KS0080551	DNP
KS0080837	2.2
KS0080845	DNP
KS0080861	DNP
KS0080900	DNP
KS0081230	DNP
KS0081345	DNP
KS0081400	DNP
KS0081566	DNP
KS0081639	DNP
KS0081698	DNP
KS0082473	DNP
KS0082597	DNP
KS0082694	DNP
KS0083577	DNP
KS0084077	DNP
KS0084174	DNP
KS0084484	DNP
KS0085201	DNP
KS0085588	DNP
KS0115479	DNP
KS0115487	DNP
KS0115525	DNP
KS0115584	DNP
KS0115606	DNP

NPID	Average Design Flow (MGD)
KS0115762	DNP
KS0115819	DNP
KS0115827	DNP
KS0115835	DNP
KS0115851	DNP
KS0116122	DNP
KS0116327	DNP
KS0116378	DNP
KS0116491	DNP
KS0117021	DNP
KS0117129	DNP
KS0117412	DNP
KS0117846	DNP
KS0117871	DNP
KS0118354	DNP
KS0118508	DNP
KS0118516	DNP
KS0118621	DNP
KS0118681	DNP
KS0118737	DNP
KS0118745	DNP
KS0118931	DNP
KS0118958	DNP
KS0118966	DNP
KS0118991	DNP
KS0119130	DNP
KS0119164	DNP
KS0119229	DNP
KS0119237	DNP
KS0119261	DNP
KS0119270	DNP
KS0119431	DNP
KS0119458	DNP
KS0119491	DNP
KS0119521	DNP
KS0119806	DNP
MO0002313	1.460
MO0002348	203.5
MO0002356	0.020
MO0002364	DNP
MO0002372	2.600
MO0002381	0.008
MO0002402	1.000
MO0002411	0.002
MO0002429	0.040
MO0002437	0.006
MO0002453	6.000
MO0002470	0.090
MO0002500	0.900
MO0002518	0.100

NPID	Average Design Flow (MGD)
MO0004073	0.400
MO0021440	6.000
MO0022381	1.000
MO0023159	0.200
MO0023256	7.000
MO0023264	8.500
MO0025186	0.420
MO0025801	0.620
MO0028657	0.182
MO0031658	0.125
MO0034410	0.010
MO0035548	0.008
MO0036757	1.015
MO0036765	0.040
MO0036773	0.405
MO0039136	2.700
MO0039926	3.000
MO0040185	1.400
MO0040193	0.480
MO0041149	0.096
MO0042013	0.208
MO0044172	0.900
MO0044202	0.477
MO0044750	0.006
MO0045641	0.008
MO0049948	0.002
MO0053627	0.142
MO0053970	0.016
MO0054101	0.073
MO0054721	0.200
MO0058327	0.036
MO0082627	0.015
MO0082767	0.018
MO0083411	0.065
MO0083917	0.005
MO0085821	0.008
MO0088277	DNP
MO0089036	0.100
MO0092525	0.107
MO0093998	DNP
MO0095362	1.000
MO0096270	0.005
MO0096679	0.075
MO0097080	0.002
MO0097446	0.019
MO0097829	DNP
MO0098272	0.002
MO0098833	0.020
MO0099155	0.200
MO0099309	0.200

NPID	Average Design Flow (MGD)
MO0100251	0.002
MO0100421	DNP
MO0102253	0.056
MO0103349	6.000
MO0104469	DNP
MO0104884	DNP
MO0104906	5.000
MO0105678	0.007
MO0106135	0.005
MO0106283	0.050
MO0106381	0.008
MO0106861	0.001
MO0107107	0.008
MO0107166	0.001
MO0107573	0.002
MO0107581	0.220
MO0108677	0.150
MO0108731	DNP
MO0108766	0.037
MO0108782	DNP
MO0108871	DNP
MO0108952	0.009
MO0109274	0.023
MO0109541	6.000
MO0110272	DNP
MO0110299	0.003
MO0110426	DNP
MO0111023	0.150
MO0111309	DNP
MO0111317	DNP
MO0111325	DNP
MO0111741	DNP
MO0111791	0.003
MO0112046	DNP
MO0112101	0.402
MO0112119	0.961
MO0112372	0.036
MO0112534	0.172
MO0112631	0.029
OK0001040	DNP
OK0001261	DNP
OK0020320	0.320
OK0020656	0.14
OK0021172	0.015
OK0021458	0.025
OK0021504	0.115
OK0028258	0.13
OK0028291	0.1
OK0028886	0.288
OK0030236	0.353

NPID	Average Design Flow (MGD)
OK0031798	1.500
OK0031801	0.55
OK0031976	0.88
OK0032263	0.218
OK0034789	0.015
OK0034835	0.004
OK0037036	0.034
OK0037770	0.020
OK0037842	0.04
OK0037869	0.038
OK0037915	0.009
OK0037923	0.050
OK0037991	0.015
OK0038041	0.012
OK0038598	DNP
OK0038687	DNP
OK0038962	0.0325
OK0039039	0.01
OK0039098	0.02
OK0039144	0.013
OK0040142	DNP
OK0041009	DNP
OK0041025	DNP

DNP = DATA NOT PROVIDED.

STATE	FLOW (MGD)	# NPID's INCLUDED	# NPID's IN-STATE	% TOTAL NPID FLOW
ARKANSAS	1	2	5	0
KANSAS	100	11	131	27
MISSOURI	273	86	103	72
OKLAHOMA	5	27	34	1
TOTALS	379	126	273	100

NPID	Design criteria (parameter)
AR0020273	BOD, 5-DAY (20 DEG. C)
AR0020273	BOD, CARBONACEOUS 05 DAY, 20C
AR0020273	COLIFORM, FECAL GENERAL
AR0020273	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
AR0020273	NITROGEN, AMMONIA TOTAL (AS N)
AR0020273	OXYGEN, DISSOLVED (DO)
AR0020273	PH
AR0020273	SOLIDS, TOTAL SUSPENDED
AR0023833	BOD, CARBONACEOUS 05 DAY, 20C
AR0023833	COLIFORM, FECAL GENERAL
AR0023833	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
AR0023833	NITROGEN, AMMONIA TOTAL (AS N)
AR0023833	PH
AR0023833	SOLIDS, TOTAL SUSPENDED
AR0034258	BOD, 5-DAY (20 DEG. C)
AR0034258	COLIFORM, FECAL GENERAL
AR0034258	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
AR0034258	PH
AR0034258	SOLIDS, TOTAL SUSPENDED
AR0036480	BOD, 5-DAY (20 DEG. C)
AR0036480	COLIFORM, FECAL GENERAL
AR0036480	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
AR0036480	PH
AR0036480	SOLIDS, TOTAL SUSPENDED
AR0041904	DATA NOT PROVIDED
KS0000469	DATA NOT PROVIDED
KS0000477	DATA NOT PROVIDED
KS0000493	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0000493	NITROGEN, AMMONIA TOTAL (AS N)
KS0000493	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
KS0000493	PH
KS0000493	TEMPERATURE, WATER DEG. FAHRENHEIT
KS0000612	DATA NOT PROVIDED
KS0000701	DATA NOT PROVIDED
KS0000736	DATA NOT PROVIDED
KS0000795	DATA NOT PROVIDED
KS0000817	BOD, 5-DAY (20 DEG. C)
KS0000817	CHLORINE, TOTAL RESIDUAL
KS0000817	COLIFORM, FECAL GENERAL
KS0000817	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0000817	NITROGEN, AMMONIA TOTAL (AS N)
KS0000817	OIL AND GREASE (SOXHLET EXTR.) TOT.
KS0000817	PH
KS0000817	SOLIDS, TOTAL SUSPENDED
KS0000817	TEMPERATURE, WATER DEG. FAHRENHEIT
KS0001180	DATA NOT PROVIDED
KS0001201	DATA NOT PROVIDED
KS0001279	DATA NOT PROVIDED
KS0001295	DATA NOT PROVIDED
KS0001309	DATA NOT PROVIDED

NPID	Design criteria (parameter)
KS0001325	DATA NOT PROVIDED
KS0001350	DATA NOT PROVIDED
KS0021393	DATA NOT PROVIDED
KS0022551	BOD, 5-DAY (20 DEG. C)
KS0022551	BOD, 5-DAY PERCENT REMOVAL
KS0022551	PH
KS0022551	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0022551	SOLIDS, TOTAL SUSPENDED
KS0022632	BOD, 5-DAY (20 DEG. C)
KS0022632	BOD, 5-DAY PERCENT REMOVAL
KS0022632	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0022632	PH
KS0022632	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0022632	SOLIDS, TOTAL SUSPENDED
KS0024732	DATA NOT PROVIDED
KS0024767	DATA NOT PROVIDED
KS0025526	DATA NOT PROVIDED
KS0025682	BOD, 5-DAY (20 DEG. C)
KS0025682	BOD, 5-DAY PERCENT REMOVAL
KS0025682	PH
KS0025682	SOLIDS, TOTAL SUSPENDED
KS0026131	BOD, 5-DAY (20 DEG. C)
KS0026131	BOD, 5-DAY PERCENT REMOVAL
KS0026131	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0026131	PH
KS0026131	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0026131	SOLIDS, TOTAL SUSPENDED
KS0026221	BOD, 5-DAY (20 DEG. C)
KS0026221	BOD, 5-DAY PERCENT REMOVAL
KS0026221	PH
KS0026221	SOLIDS, TOTAL SUSPENDED
KS0026417	DATA NOT PROVIDED
KS0027898	BOD, 5-DAY (20 DEG. C)
KS0027898	BOD, 5-DAY PERCENT REMOVAL
KS0027898	PH
KS0027898	SOLIDS, TOTAL SUSPENDED
KS0028533	BOD, 5-DAY (20 DEG. C)
KS0028533	BOD, 5-DAY PERCENT REMOVAL
KS0028533	PH
KS0028533	SOLIDS, TOTAL SUSPENDED
KS0029360	BOD, 5-DAY (20 DEG. C)
KS0029360	CHLORINE, TOTAL RESIDUAL
KS0029360	COPPER, TOTAL (AS CU)
KS0029360	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0029360	IRON, TOTAL (AS FE)
KS0029360	LEAD, TOTAL (AS PB)
KS0029360	MERCURY TOTAL RECOVERABLE
KS0029360	NITROGEN, AMMONIA TOTAL (AS N)
KS0029360	NITROGEN, TOTAL (AS N)
KS0029360	OIL AND GREASE (SOXHLET EXTR.) TOT.

NPID	Design criteria (parameter)
KS0029360	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
KS0029360	PH
KS0029360	PHOSPHATE, TOTAL (AS PO4)
KS0029360	RDX, DISSOLVED
KS0029360	RDX, TOTAL
KS0029360	SOLIDS, TOTAL SUSPENDED
KS0029360	TRINITROTOLUENE (TNT), TOTAL
KS0030589	DATA NOT PROVIDED
KS0030813	DATA NOT PROVIDED
KS0031135	BOD, 5-DAY (20 DEG. C)
KS0031135	BOD, 5-DAY PERCENT REMOVAL
KS0031135	PH
KS0031135	SOLIDS, TOTAL SUSPENDED
KS0031178	DATA NOT PROVIDED
KS0031445	BOD, 5-DAY (20 DEG. C)
KS0031445	BOD, 5-DAY PERCENT REMOVAL
KS0031445	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0031445	PH
KS0031445	SOLIDS, TOTAL SUSPENDED
KS0032123	BOD, 5-DAY (20 DEG. C)
KS0032123	BOD, 5-DAY PERCENT REMOVAL
KS0032123	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0032123	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0032123	NITROGEN, AMMONIA TOTAL (AS N)
KS0032123	PH
KS0032123	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0032123	SOLIDS, TOTAL SUSPENDED
KS0036722	BOD, 5-DAY (20 DEG. C)
KS0036722	BOD, 5-DAY PERCENT REMOVAL
KS0036722	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0036722	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0036722	NITROGEN, AMMONIA TOTAL (AS N)
KS0036722	OXYGEN, DISSOLVED (DO)
KS0036722	PH
KS0036722	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0036722	SOLIDS, TOTAL SUSPENDED
KS0037672	DATA NOT PROVIDED
KS0038652	BOD, 5-DAY (20 DEG. C)
KS0038652	BOD, 5-DAY PERCENT REMOVAL
KS0038652	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0038652	PH
KS0038652	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0038652	SOLIDS, TOTAL SUSPENDED
KS0038954	BOD, 5-DAY (20 DEG. C)
KS0038954	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0038954	CHLORIDE (AS CL)
KS0038954	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0038954	NITROGEN, AMMONIA TOTAL (AS N)
KS0038954	PH
KS0038954	SOLIDS, TOTAL SUSPENDED

NPID	Design criteria (parameter)
KS0041572	DATA NOT PROVIDED
KS0041726	DATA NOT PROVIDED
KS0045918	BOD, 5-DAY (20 DEG. C)
KS0045918	BOD, 5-DAY PERCENT REMOVAL
KS0045918	PH
KS0045918	SOLIDS, TOTAL SUSPENDED
KS0045926	DATA NOT PROVIDED
KS0045934	BOD, 5-DAY (20 DEG. C)
KS0045934	BOD, 5-DAY PERCENT REMOVAL
KS0045934	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0045934	PH
KS0045934	SOLIDS, TOTAL SUSPENDED
KS0045977	DATA NOT PROVIDED
KS0045993	DATA NOT PROVIDED
KS0046043	DATA NOT PROVIDED
KS0046728	BOD, 5-DAY (20 DEG. C)
KS0046728	BOD, 5-DAY PERCENT REMOVAL
KS0046728	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0046728	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0046728	NITROGEN, AMMONIA TOTAL (AS N)
KS0046728	PH
KS0046728	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0046728	SOLIDS, TOTAL SUSPENDED
KS0047406	BOD, 5-DAY (20 DEG. C)
KS0047406	BOD, 5-DAY PERCENT REMOVAL
KS0047406	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0047406	PH
KS0047406	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0047406	SOLIDS, TOTAL SUSPENDED
KS0047554	BOD, 5-DAY (20 DEG. C)
KS0047554	BOD, 5-DAY PERCENT REMOVAL
KS0047554	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0047554	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0047554	PH
KS0047554	SOLIDS, TOTAL SUSPENDED
KS0047571	DATA NOT PROVIDED
KS0048135	BOD, 5-DAY (20 DEG. C)
KS0048135	BOD, 5-DAY PERCENT REMOVAL
KS0048135	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0048135	PH
KS0048135	SOLIDS, TOTAL SUSPENDED
KS0051268	DATA NOT PROVIDED
KS0051659	BOD, 5-DAY (20 DEG. C)
KS0051659	BOD, 5-DAY PERCENT REMOVAL
KS0051659	PH
KS0051659	SOLIDS, TOTAL SUSPENDED
KS0051675	BOD, 5-DAY (20 DEG. C)
KS0051675	BOD, 5-DAY PERCENT REMOVAL
KS0051675	PH
KS0051675	SOLIDS, TOTAL SUSPENDED

NPID	Design criteria (parameter)
KS0051691	BOD, 5-DAY (20 DEG. C)
KS0051691	BOD, 5-DAY PERCENT REMOVAL
KS0051691	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0051691	NITROGEN, AMMONIA TOTAL (AS N)
KS0051691	PH
KS0051691	SOLIDS, TOTAL SUSPENDED
KS0051705	BOD, 5-DAY (20 DEG. C)
KS0051705	BOD, 5-DAY PERCENT REMOVAL
KS0051705	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0051705	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0051705	NITROGEN, AMMONIA TOTAL (AS N)
KS0051705	PH
KS0051705	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0051705	SOLIDS, TOTAL SUSPENDED
KS0053660	BOD, 5-DAY (20 DEG. C)
KS0053660	BOD, 5-DAY PERCENT REMOVAL
KS0053660	PH
KS0053660	SOLIDS, TOTAL SUSPENDED
KS0053678	BOD, 5-DAY (20 DEG. C)
KS0053678	BOD, 5-DAY PERCENT REMOVAL
KS0053678	PH
KS0053678	SOLIDS, TOTAL SUSPENDED
KS0079057	BOD, 5-DAY (20 DEG. C)
KS0079057	CHLORIDE (AS CL)
KS0079057	CHLORINE, TOTAL RESIDUAL
KS0079057	COLIFORM, FECAL GENERAL
KS0079057	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0079057	OIL AND GREASE (SOXHLET EXTR.) TOT.
KS0079057	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
KS0079057	PH
KS0079057	SOLIDS, TOTAL DISSOLVED (TDS)
KS0079057	SOLIDS, TOTAL SUSPENDED
KS0079057	SULFATE, TOTAL (AS SO4)
KS0079057	SURFACTANTS (MBAS)
KS0079057	TEMPERATURE, WATER DEG. FAHRENHEIT
KS0079146	DATA NOT PROVIDED
KS0079472	ACIDITY, TOTAL (AS CACO3)
KS0079472	ALKALINITY, TOTAL (AS CACO3)
KS0079472	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0079472	IRON, TOTAL (AS FE)
KS0079472	MANGANESE, TOTAL (AS MN)
KS0079472	PH
KS0079472	SOLIDS, SETTLEABLE
KS0079472	SOLIDS, TOTAL SUSPENDED
KS0079481	DATA NOT PROVIDED
KS0079529	ACIDITY, TOTAL (AS CACO3)
KS0079529	ALKALINITY, TOTAL (AS CACO3)
KS0079529	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0079529	IRON, TOTAL (AS FE)
KS0079529	MANGANESE, SUSPENDED

NPID	Design criteria (parameter)
KS0079529	MANGANESE, TOTAL (AS MN)
KS0079529	PH
KS0079529	SOLIDS, SETTLEABLE
KS0079529	SOLIDS, TOTAL SUSPENDED
KS0079766	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0079766	IRON, TOTAL (AS FE)
KS0079766	MAGNESIUM, TOTAL (AS MG)
KS0079766	PH
KS0079766	SOLIDS, SETTLEABLE
KS0079766	SOLIDS, TOTAL SUSPENDED
KS0079812	CHLORINE, TOTAL RESIDUAL
KS0079812	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0079812	OIL AND GREASE (SOXHLET EXTR.) TOT.
KS0079812	PH
KS0079812	SOLIDS, TOTAL SUSPENDED
KS0079812	TEMPERATURE, WATER DEG. FAHRENHEIT
KS0079880	DATA NOT PROVIDED
KS0079952	DATA NOT PROVIDED
KS0080225	DATA NOT PROVIDED
KS0080349	DATA NOT PROVIDED
KS0080357	DATA NOT PROVIDED
KS0080551	DATA NOT PROVIDED
KS0080837	BOD, 5-DAY (20 DEG. C)
KS0080837	BOD, 5-DAY PERCENT REMOVAL
KS0080837	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0080837	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0080837	NITROGEN, AMMONIA TOTAL (AS N)
KS0080837	PH
KS0080837	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0080837	SOLIDS, TOTAL SUSPENDED
KS0080845	DATA NOT PROVIDED
KS0080861	DATA NOT PROVIDED
KS0080900	BOD, 5-DAY (20 DEG. C)
KS0080900	BOD, 5-DAY PERCENT REMOVAL
KS0080900	PH
KS0080900	SOLIDS, TOTAL SUSPENDED
KS0081230	BOD, 5-DAY (20 DEG. C)
KS0081230	BOD, 5-DAY PERCENT REMOVAL
KS0081230	PH
KS0081230	SOLIDS, TOTAL SUSPENDED
KS0081345	DATA NOT PROVIDED
KS0081400	DATA NOT PROVIDED
KS0081566	BOD, 5-DAY (20 DEG. C)
KS0081566	BOD, 5-DAY PERCENT REMOVAL
KS0081566	PH
KS0081566	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0081566	SOLIDS, TOTAL SUSPENDED
KS0081639	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0081639	IRON, TOTAL (AS FE)
KS0081639	MANGANESE, TOTAL (AS MN)

NPID	Design criteria (parameter)
KS0081639	PH
KS0081639	SOLIDS, SETTLEABLE
KS0081639	SOLIDS, TOTAL SUSPENDED
KS0081698	DATA NOT PROVIDED
KS0082473	DATA NOT PROVIDED
KS0082597	DATA NOT PROVIDED
KS0082694	DATA NOT PROVIDED
KS0083577	BOD, 5-DAY (20 DEG. C)
KS0083577	BOD, 5-DAY PERCENT REMOVAL
KS0083577	PH
KS0083577	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0083577	SOLIDS, TOTAL SUSPENDED
KS0084077	DATA NOT PROVIDED
KS0084174	DATA NOT PROVIDED
KS0084484	DATA NOT PROVIDED
KS0085201	BOD, 5-DAY (20 DEG. C)
KS0085201	BOD, 5-DAY PERCENT REMOVAL
KS0085201	BOD, NITROG INHIB 5-DAY (20 DEG. C)
KS0085201	PH
KS0085201	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0085201	SOLIDS, TOTAL SUSPENDED
KS0085588	DATA NOT PROVIDED
KS0115479	DATA NOT PROVIDED
KS0115487	DATA NOT PROVIDED
KS0115525	DATA NOT PROVIDED
KS0115584	BOD, 5-DAY (20 DEG. C)
KS0115584	BOD, 5-DAY PERCENT REMOVAL
KS0115584	PH
KS0115584	SOLIDS, TOTAL SUSPENDED
KS0115606	DATA NOT PROVIDED
KS0115762	DATA NOT PROVIDED
KS0115819	DATA NOT PROVIDED
KS0115827	DATA NOT PROVIDED
KS0115835	DATA NOT PROVIDED
KS0115851	DATA NOT PROVIDED
KS0116122	BOD, 5-DAY (20 DEG. C)
KS0116122	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0116122	PH
KS0116122	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0116122	SOLIDS, TOTAL SUSPENDED
KS0116327	DATA NOT PROVIDED
KS0116378	DATA NOT PROVIDED
KS0116491	DATA NOT PROVIDED
KS0117021	DATA NOT PROVIDED
KS0117129	DATA NOT PROVIDED
KS0117412	DATA NOT PROVIDED
KS0117846	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0117846	NITROGEN, AMMONIA TOTAL (AS N)
KS0117846	NITROGEN, NITRATE TOTAL (AS N)
KS0117846	PH

NPID	Design criteria (parameter)
KS0117871	BOD, 5-DAY (20 DEG. C)
KS0117871	BOD, 5-DAY PERCENT REMOVAL
KS0117871	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
KS0117871	PH
KS0117871	SOLIDS, SUSPENDED PERCENT REMOVAL
KS0117871	SOLIDS, TOTAL SUSPENDED
KS0118354	DATA NOT PROVIDED
KS0118508	DATA NOT PROVIDED
KS0118516	DATA NOT PROVIDED
KS0118621	DATA NOT PROVIDED
KS0118681	DATA NOT PROVIDED
KS0118737	DATA NOT PROVIDED
KS0118745	DATA NOT PROVIDED
KS0118931	DATA NOT PROVIDED
KS0118958	DATA NOT PROVIDED
KS0118966	DATA NOT PROVIDED
KS0118991	DATA NOT PROVIDED
KS0119130	DATA NOT PROVIDED
KS0119164	DATA NOT PROVIDED
KS0119229	DATA NOT PROVIDED
KS0119237	DATA NOT PROVIDED
KS0119261	DATA NOT PROVIDED
KS0119270	DATA NOT PROVIDED
KS0119431	DATA NOT PROVIDED
KS0119458	DATA NOT PROVIDED
KS0119491	DATA NOT PROVIDED
KS0119521	DATA NOT PROVIDED
KS0119806	DATA NOT PROVIDED
MO0002313	BOD, 5-DAY (20 DEG. C)
MO0002313	CARBON, TOT ORGANIC (TOC)
MO0002313	DATA NOT PROVIDED
MO0002313	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002313	NITROGEN, AMMONIA TOTAL (AS N)
MO0002313	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0002313	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0002313	PH
MO0002313	RAINFALL
MO0002313	SOLIDS, TOTAL SUSPENDED
MO0002313	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0002348	BORON, TOTAL (AS B)
MO0002348	CADMIUM, TOTAL (AS CD)
MO0002348	CHLORIDES & SULFATES
MO0002348	CHROMIUM, TOTAL (AS CR)
MO0002348	COBALT, TOTAL (AS CO)
MO0002348	COPPER, TOTAL (AS CU)
MO0002348	DATA NOT PROVIDED
MO0002348	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002348	LEAD, TOTAL (AS PB)
MO0002348	NICKEL, TOTAL (AS NI)
MO0002348	NITROGEN, AMMONIA TOTAL (AS N)

NPID	Design criteria (parameter)
MO0002348	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0002348	ORGANICS, TOTAL TOXIC (TTO)
MO0002348	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0002348	PH
MO0002348	SILVER, TOTAL (AS AG)
MO0002348	SOLIDS, TOTAL SUSPENDED
MO0002348	SPECIFIC CONDUCTANCE
MO0002348	ZINC, TOTAL (AS ZN)
MO0002356	BOD, 5-DAY (20 DEG. C)
MO0002356	CARBON, TOT ORGANIC (TOC)
MO0002356	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002356	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0002356	PH
MO0002356	SOLIDS, TOTAL SUSPENDED
MO0002356	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0002364	ACIDITY, TOTAL (AS CACO3)
MO0002364	ALKALINITY, TOTAL (AS CACO3)
MO0002364	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002364	IRON, TOTAL (AS FE)
MO0002364	MANGANESE, TOTAL (AS MN)
MO0002364	PH
MO0002364	RAINFALL
MO0002364	SOLIDS, SETTLEABLE
MO0002364	SOLIDS, TOTAL SUSPENDED
MO0002372	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002372	PH
MO0002372	SOLIDS, SETTLEABLE
MO0002372	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0002381	DATA NOT PROVIDED
MO0002381	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002381	PH
MO0002381	SOLIDS, TOTAL SUSPENDED
MO0002402	BOD, 5-DAY (20 DEG. C)
MO0002402	BOD, 5-DAY(20 DEG.C)PER PRODUCTION
MO0002402	CHEM. OXYGEN DEMAND PER PRODUCTION
MO0002402	ETHYLENE GLYCOL DINITRATE
MO0002402	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002402	LEAD, TOTAL (AS PB)
MO0002402	NITROGEN, AMMONIA TOTAL (AS N)
MO0002402	NITROGEN, NITRATE TOTAL (AS N)
MO0002402	NITROGEN, ORGANIC TOTAL (AS N)
MO0002402	NITROGLYCERIN BY GAS CHROMATOGRAPHY
MO0002402	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0002402	OIL AND GREASE PER PRODUCTION
MO0002402	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0002402	PH
MO0002402	SOLIDS, TOTAL SUSPENDED
MO0002402	SOLIDS, TOTAL SUSP PER PRODUCTION
MO0002402	SULFATE, TOTAL (AS SO4)
MO0002402	TEMPERATURE, WATER DEG. FAHRENHEIT

NPID	Design criteria (parameter)
MO0002402	ZINC, TOTAL (AS ZN)
MO0002411	1,1,1-TRICHLORO- ETHANE
MO0002411	1,1-DICHLOROETHANE
MO0002411	1,1-DICHLOROETHYLENE
MO0002411	1,2-DICHLOROETHANE, TOTAL WEIGHT
MO0002411	1,2-TRANS-DICHLORO- ETHYLENE
MO0002411	2-CHLOROETHYL VINYL ETHER (MIXED)
MO0002411	ARSENIC, TOTAL (AS AS)
MO0002411	BARIUM, TOTAL (AS BA)
MO0002411	BOD, 5-DAY (20 DEG. C)
MO0002411	CADMIUM, TOTAL (AS CD)
MO0002411	CARBON TETRACHLORIDE
MO0002411	CHLOROETHANE, TOTAL WEIGHT
MO0002411	CHLOROFORM
MO0002411	CHROMIUM, TOTAL (AS CR)
MO0002411	CYANIDE, TOTAL (AS CN)
MO0002411	ETHYL BENZENE
MO0002411	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002411	LEAD, TOTAL (AS PB)
MO0002411	METHYLENE CHLORIDE
MO0002411	NICKEL, TOTAL (AS NI)
MO0002411	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0002411	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0002411	PH
MO0002411	SOLIDS, SETTLEABLE
MO0002411	SOLIDS, TOTAL SUSPENDED
MO0002411	TETRACHLOROETHYLENE
MO0002411	TOLUENE
MO0002411	TRICHLOROETHYLENE
MO0002411	VINYL CHLORIDE
MO0002411	ZINC, DISSOLVED (AS ZN)
MO0002411	ZINC, TOTAL (AS ZN)
MO0002429	DATA NOT PROVIDED
MO0002429	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002429	FLUORIDE, TOTAL (AS F)
MO0002429	NITROGEN, AMMONIA TOTAL (AS N)
MO0002429	PH
MO0002429	PHOSPHORUS, TOTAL (AS P)
MO0002429	RAINFALL
MO0002429	SOLIDS, TOTAL SUSPENDED
MO0002429	SULFATE (AS S)
MO0002429	SULFATE, TOTAL (AS SO4)
MO0002429	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0002437	AMMONIA, UNIONIZED
MO0002437	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002437	PH
MO0002437	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0002453	APPLICATION RATEAREA SPRAYED
MO0002453	BOD, 5-DAY(20 DEG. C)
MO0002453	CADMIUM, TOTAL(AS CD)

NPID	Design criteria (parameter)
MO0002453	CHLORIDES & SULFATES
MO0002453	CHROMIUM, HEXAVALENT(AS CR)
MO0002453	CHROMIUM, TOTAL(AS CR)
MO0002453	CHROMIUMTOTAL RECOVERABLE
MO0002453	COPPER, TOTAL(AS CU)
MO0002453	COPPERTOTAL RECOVERABLE
MO0002453	DEPTH TO WATER LEVELFT BELOW LANDSURFACE
MO0002453	ETHYLENE GLYCOLDINITRATE
MO0002453	FLOW RATE
MO0002453	FLOW, GALLONS/BATCH
MO0002453	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0002453	LEAD, TOTAL(AS PB)
MO0002453	NICKEL, TOTAL(AS NI)
MO0002453	NITRITE PLUS NITRATETOTAL 1 DET. (AS N)
MO0002453	NITROGEN, AMMONIATOTAL (AS N)
MO0002453	NITROGEN, NITRATETOTAL (AS N)
MO0002453	NITROGEN, ORGANICTOTAL (AS N)
MO0002453	NITROGEN, TOTAL(AS N)
MO0002453	NITROGLYCERIN BY GAS CHROMATOGRAPHY
MO0002453	OIL AND GREASE(SOXHLET EXTR.) TOT.
MO0002453	OXYGEN DEMAND, CHEM.(HIGH LEVEL) (COD)
MO0002453	PH
MO0002453	PHOPTMON
MO0002453	RAINFALL
MO0002453	SOLIDS, TOTALDISSOLVED- 180 DEG.C
MO0002453	SOLIDS, TOTALSUSPENDED
MO0002453	SPRAY IRRIGATION
MO0002453	SULFATE, TOTAL(AS SO4)
MO0002453	TEMPERATURE, WATERDEG. FAHRENHEIT
MO0002453	ZINC, TOTAL (AS ZN)
MO0002470	BOD, 5-DAY (20 DEG.C)
MO0002470	COLIFORM, FECAL GENERAL
MO0002470	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002470	NITROGEN, AMMONIA TOTAL (AS N)
MO0002470	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0002470	PH
MO0002470	SOLIDS, TOTAL SUSPENDED
MO0002500	BOD, 5-DAY (20 DEG. C)
MO0002500	CHLORINE, TOTAL RESIDUAL
MO0002500	COLIFORM, FECAL GENERAL
MO0002500	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002500	PH
MO0002500	SOLIDS, TOTAL SUSPENDED
MO0002518	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0002518	MERCURY, TOTAL (AS HG)
MO0002518	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0002518	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0002518	PH
MO0002518	SILVER, DISSOLVED (AS AG)
MO0002518	SOLIDS, TOTAL SUSPENDED

NPID	Design criteria (parameter)
MO0004073	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0004073	PH
MO0004073	SOLIDS, TOTAL SUSPENDED
MO0021440	BOD, 5-DAY(20 DEG. C)
MO0021440	CADMIUMTOTAL RECOVERABLE
MO0021440	CHLORINE, TOTALRESIDUAL
MO0021440	CHROMIUM, HEXAVALENTDISSOLVED (AS CR)
MO0021440	COLIFORM, FECALGENERAL
MO0021440	COPPERTOTAL RECOVERABLE
MO0021440	CYANIDE,FREE (AMEN.TO CHLORINATION)
MO0021440	DATA NOT PROVIDED
MO0021440	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0021440	LEADTOTAL RECOVERABLE
MO0021440	NICKELTOTAL RECOVERABLE
MO0021440	NITROGEN, AMMONIATOTAL (AS N)
MO0021440	OIL AND GREASE(SOXHLET EXTR.) TOT.
MO0021440	PH
MO0021440	SOLIDS, TOTALSUSPENDED
MO0021440	TEMPERATURE, WATERDEG. FAHRENHEIT
MO0021440	ZINCTOTAL RECOVERABLE
MO0022381	BOD, 5-DAY(20 DEG. C)
MO0022381	CADMIUM, TOTAL(AS CD)
MO0022381	CHLORINE, TOTALRESIDUAL
MO0022381	CHROMIUM, TOTAL(AS CR)
MO0022381	COLIFORM, FECALGENERAL
MO0022381	COPPER, TOTAL(AS CU)
MO0022381	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0022381	NICKEL, TOTAL(AS NI)
MO0022381	NITROGEN, AMMONIATOTAL (AS N)
MO0022381	OIL AND GREASE(SOXHLET EXTR.) TOT.
MO0022381	PH
MO0022381	SOLIDS, TOTALSUSPENDED
MO0022381	ZINC, TOTAL (AS ZN)
MO0023159	BOD, 5-DAY (20 DEG. C)
MO0023159	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0023159	PH
MO0023159	SOLIDS, TOTAL SUSPENDED
MO0023256	ARSENIC, TOTAL RECOVERABLE
MO0023256	BOD, 5-DAY(20 DEG. C)
MO0023256	CADMIUMTOTAL RECOVERABLE
MO0023256	CHLORINE, TOTALRESIDUAL
MO0023256	CHROMIUMTOTAL RECOVERABLE
MO0023256	COLIFORM, FECALGENERAL
MO0023256	COPPERTOTAL RECOVERABLE
MO0023256	CYANIDE,FREE (AMEN.TO CHLORINATION)
MO0023256	DATA NOT PROVIDED
MO0023256	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0023256	LEADTOTAL RECOVERABLE
MO0023256	MERCURYTOTAL RECOVERABLE
MO0023256	NICKELTOTAL RECOVERABLE

NPID	Design criteria (parameter)
MO0023256	ORGANICS, TOTALTOXIC (TTO)
MO0023256	PH
MO0023256	SOLIDS, TOTALSUSPENDED
MO0023256	ZINCTOTAL RECOVERABLE
MO0023264	ARSENIC, TOTAL (AS AS)
MO0023264	BIS (2-ETHYLHEXYL) PHTHALATE
MO0023264	BOD, 5-DAY (20 DEG. C)
MO0023264	CADMIUM, TOTAL (AS CD)
MO0023264	CHROMIUM, TOTAL (AS CR)
MO0023264	CHRYSENE
MO0023264	COPPER, TOTAL (AS CU)
MO0023264	CYANIDE, TOTAL (AS CN)
MO0023264	DATA NOT PROVIDED
MO0023264	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0023264	FLUORENE
MO0023264	LEAD, TOTAL (AS PB)
MO0023264	MERCURY, TOTAL (AS HG)
MO0023264	METHYLENE CHLORIDE
MO0023264	NICKEL, TOTAL (AS NI)
MO0023264	ORGANICS, TOTAL TOXIC (TTO)
MO0023264	PENTACHLOROPHENOL
MO0023264	PH
MO0023264	PHENANTHRENE
MO0023264	PHENOL, SINGLE COMPOUND
MO0023264	SOLIDS, TOTAL SUSPENDED
MO0023264	ZINC, TOTAL (AS ZN)
MO0025186	BOD, 5-DAY(20 DEG. C)
MO0025186	COLIFORM, FECALGENERAL
MO0025186	DATA NOT PROVIDED
MO0025186	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0025186	PH
MO0025186	SOLIDS, TOTALSUSPENDED
MO0025801	BOD, 5-DAY (20 DEG. C)
MO0025801	COLIFORM, FECAL GENERAL
MO0025801	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0025801	PH
MO0025801	SOLIDS, TOTAL SUSPENDED
MO0028657	BOD, 5-DAY (20 DEG. C)
MO0028657	COLIFORM, FECAL GENERAL
MO0028657	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0028657	PH
MO0028657	SOLIDS, TOTAL SUSPENDED
MO0031658	BOD, 5-DAY(20 DEG. C)
MO0031658	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0031658	PH
MO0031658	SOLIDS, TOTALSUSPENDED
MO0034410	BOD, 5-DAY (20 DEG. C)
MO0034410	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0034410	PH
MO0034410	SOLIDS, TOTAL SUSPENDED

NPID	Design criteria (parameter)
MO0035548	BOD, 5-DAY (20 DEG. C)
MO0035548	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0035548	PH
MO0035548	SOLIDS, TOTAL SUSPENDED
MO0036757	BOD, 5-DAY (20 DEG. C)
MO0036757	CADMIUM TOTAL RECOVERABLE
MO0036757	CADMIUM, DISSOLVED (AS CD)
MO0036757	CADMIUM, TOTAL (AS CD)
MO0036757	COLIFORM, FECAL GENERAL
MO0036757	CYANIDE,FREE (AMEN. TO CHLORINATION)
MO0036757	DATA NOT PROVIDED
MO0036757	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0036757	NITROGEN, AMMONIA TOTAL (AS N)
MO0036757	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0036757	ORGANICS, TOTAL TOXIC (TTO)
MO0036757	PH
MO0036757	SILVER, DISSOLVED (AS AG)
MO0036757	SOLIDS, TOTAL
MO0036757	SOLIDS, TOTAL SUSPENDED
MO0036757	ZINC TOTAL RECOVERABLE
MO0036757	ZINC, DISSOLVED (AS ZN)
MO0036757	ZINC, TOTAL (AS ZN)
MO0036765	BOD, 5-DAY (20 DEG. C)
MO0036765	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0036765	PH
MO0036765	SOLIDS, TOTAL SUSPENDED
MO0036773	AMMONIA, UNIONIZED
MO0036773	BOD, 5-DAY (20 DEG. C)
MO0036773	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0036773	NITRITE PLUS NITRATE TOTAL 1 DET. (AS N)
MO0036773	NITROGEN, NITRATE TOTAL (AS N)
MO0036773	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0036773	PH
MO0036773	SOLIDS, TOTAL SUSPENDED
MO0036773	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0039136	BOD, 5-DAY(20 DEG. C)
MO0039136	CADMIUM, TOTAL(AS CD)
MO0039136	CHLORINE, TOTALRESIDUAL
MO0039136	CHROMIUM, TOTAL(AS CR)
MO0039136	COLIFORM, FECALGENERAL
MO0039136	COPPER, TOTAL(AS CU)
MO0039136	CYANIDE,FREE (AMEN.TO CHLORINATION)
MO0039136	DATA NOT PROVIDED
MO0039136	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0039136	LEAD, TOTAL(AS PB)
MO0039136	NICKEL, TOTAL(AS NI)
MO0039136	NITROGEN, AMMONIATOTAL (AS N)
MO0039136	OIL AND GREASE(SOXHLET EXTR.) TOT.
MO0039136	PH
MO0039136	SILVER, TOTAL(AS AG)

NPID	Design criteria (parameter)
MO0039136	SOLIDS, TOTALSUSPENDED
MO0039136	ZINC, TOTAL (AS ZN)
MO0039926	1,2-DICHLOROETHANE, TOTAL WEIGHT
MO0039926	BOD, 5-DAY (20 DEG. C)
MO0039926	CADMIUM, DISSOLVED (AS CD)
MO0039926	CHLORINE, TOTAL RESIDUAL
MO0039926	CHROMIUM, DISSOLVED (AS CR)
MO0039926	COLIFORM, FECAL GENERAL
MO0039926	COPPER TOTAL RECOVERABLE
MO0039926	COPPER, DISSOLVED (AS CU)
MO0039926	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0039926	MERCURY, DISSOLVED (AS HG)
MO0039926	NICKEL TOTAL RECOVERABLE
MO0039926	NICKEL, DISSOLVED (AS NI)
MO0039926	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0039926	ORGANICS, TOTAL TOXIC (TTO)
MO0039926	PH
MO0039926	PHENOL, SINGLE COMPOUND
MO0039926	SOLIDS, TOTAL
MO0039926	SOLIDS, TOTAL SUSPENDED
MO0039926	SULFATE (AS S)
MO0039926	TRICHLOROETHANE
MO0039926	ZINC TOTAL RECOVERABLE
MO0039926	ZINC, DISSOLVED (AS ZN)
MO0040185	BOD, 5-DAY(20 DEG. C)
MO0040185	COLIFORM, FECALGENERAL
MO0040185	DATA NOT PROVIDED
MO0040185	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0040185	PH
MO0040185	SOLIDS, TOTALSUSPENDED
MO0040193	BOD, 5-DAY (20 DEG. C)
MO0040193	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0040193	PH
MO0040193	SOLIDS, TOTAL SUSPENDED
MO0041149	BOD, 5-DAY (20 DEG. C)
MO0041149	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0041149	PH
MO0041149	SOLIDS, TOTAL SUSPENDED
MO0042013	APPLICATION RATEAREA SPRAYED
MO0042013	BOD, 5-DAY(20 DEG. C)
MO0042013	COLIFORM, FECALGENERAL
MO0042013	DEPTH TO WATER LEVELFT BELOW LANDSURFACE
MO0042013	FLOW RATE
MO0042013	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0042013	NITROGEN, KJELDAHLTOTAL (AS N)
MO0042013	NITROGEN, NITRATETOTAL (AS NO3)
MO0042013	PH
MO0042013	PHOSPHORUS, TOTAL(AS P)
MO0042013	POTASSIUM, TOTAL(AS K)
MO0042013	RAINFALL

NPID	Design criteria (parameter)
MO0042013	SOLIDS, TOTALSUSPENDED
MO0042013	SPRAY IRRIGATION
MO0044172	BOD, 5-DAY (20 DEG. C)
MO0044172	CHROMIUM TOTAL RECOVERABLE
MO0044172	COPPER TOTAL RECOVERABLE
MO0044172	CYANIDE, TOTAL (AS CN)
MO0044172	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0044172	PH
MO0044172	SOLIDS, TOTAL SUSPENDED
MO0044172	ZINC TOTAL RECOVERABLE
MO0044202	BOD, 5-DAY (20 DEG. C)
MO0044202	COPPER, DISSOLVED (AS CU)
MO0044202	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0044202	PH
MO0044202	SOLIDS, TOTAL SUSPENDED
MO0044750	BOD, 5-DAY (20 DEG. C)
MO0044750	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0044750	PH
MO0044750	SOLIDS, TOTAL SUSPENDED
MO0045641	BOD, 5-DAY (20 DEG. C)
MO0045641	COLIFORM, FECAL GENERAL
MO0045641	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0045641	PH
MO0045641	SOLIDS, TOTAL SUSPENDED
MO0049948	BOD, 5-DAY (20 DEG. C)
MO0049948	COLIFORM, FECAL GENERAL
MO0049948	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0049948	PH
MO0049948	SOLIDS, TOTAL SUSPENDED
MO0053627	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0053627	FLUORIDE, TOTAL (AS F)
MO0053627	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0053627	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0053627	PH
MO0053627	PHOSPHORUS, TOTAL (AS P)
MO0053627	RAINFALL
MO0053627	SOLIDS, TOTAL SUSPENDED
MO0053627	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0053970	BOD, 5-DAY (20 DEG. C)
MO0053970	COLIFORM, FECAL GENERAL
MO0053970	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0053970	PH
MO0053970	SOLIDS, TOTAL SUSPENDED
MO0054101	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0054101	PH
MO0054101	SOLIDS, TOTAL SUSPENDED
MO0054101	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0054721	BOD, 5-DAY (20 DEG. C)
MO0054721	COLIFORM, FECAL GENERAL
MO0054721	FLOW, IN CONDUIT OR THRU TREATMENT PLANT

NPID	Design criteria (parameter)
MO0054721	PH
MO0054721	SOLIDS, TOTAL SUSPENDED
MO0058327	BOD, 5-DAY(20 DEG. C)
MO0058327	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0058327	PH
MO0058327	SOLIDS, TOTALSUSPENDED
MO0082627	BOD, 5-DAY (20 DEG. C)
MO0082627	COLIFORM, FECAL GENERAL
MO0082627	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0082627	PH
MO0082627	SOLIDS, TOTAL SUSPENDED
MO0082767	BOD, 5-DAY (20 DEG. C)
MO0082767	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0082767	NITROGEN, AMMONIA TOTAL (AS N)
MO0082767	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0082767	PH
MO0082767	RAINFALL
MO0082767	SOLIDS, SETTLEABLE
MO0082767	SOLIDS, TOTAL SUSPENDED
MO0083411	BOD, 5-DAY (20 DEG. C)
MO0083411	CHLORINE, TOTAL RESIDUAL
MO0083411	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0083411	NITRITE PLUS NITRATE TOTAL 1 DET. (AS N)
MO0083411	NITROGEN, TOTAL (AS N)
MO0083411	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0083411	PH
MO0083411	SOLIDS, TOTAL SUSPENDED
MO0083411	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0083917	BOD, 5-DAY (20 DEG. C)
MO0083917	COLIFORM, FECAL GENERAL
MO0083917	DATA NOT PROVIDED
MO0083917	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0083917	PH
MO0083917	SOLIDS, TOTAL SUSPENDED
MO0085821	BOD, 5-DAY (20 DEG. C)
MO0085821	COLIFORM, FECAL GENERAL
MO0085821	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0085821	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0085821	PH
MO0085821	SOLIDS, TOTAL SUSPENDED
MO0088277	CADMIUM, TOTAL (AS CD)
MO0088277	CHROMIUM, TOTAL (AS CR)
MO0088277	COPPER, TOTAL (AS CU)
MO0088277	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0088277	LEAD, TOTAL (AS PB)
MO0088277	NICKEL, TOTAL (AS NI)
MO0088277	PH
MO0088277	SOLIDS, TOTAL SUSPENDED
MO0088277	ZINC, TOTAL (AS ZN)
MO0089036	BOD, 5-DAY (20 DEG. C)

NPID	Design criteria (parameter)
MO0089036	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0089036	PH
MO0089036	SOLIDS, TOTAL SUSPENDED
MO0092525	BOD, 5-DAY (20 DEG. C)
MO0092525	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0092525	PH
MO0092525	SOLIDS, TOTAL SUSPENDED
MO0093998	BOD, 5-DAY (20 DEG. C)
MO0093998	CARBON, TOTAL (AS C)
MO0093998	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0093998	NITROGEN, AMMONIA TOTAL (AS N)
MO0093998	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0093998	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0093998	OXYGEN, DISSOLVED (DO)
MO0093998	PH
MO0093998	SOLIDS, TOTAL SUSPENDED
MO0095362	ACIDITY, TOTAL (AS CACO3)
MO0095362	CHLORINE, FREE AVAILABLE
MO0095362	COPPER TOTAL RECOVERABLE
MO0095362	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0095362	IRON TOTAL RECOVERABLE
MO0095362	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0095362	PH
MO0095362	SOLIDS, TOTAL SUSPENDED
MO0095362	SULFATE, TOTAL (AS SO4)
MO0095362	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0096270	BOD, 5-DAY (20 DEG. C)
MO0096270	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0096270	PH
MO0096270	SOLIDS, TOTAL SUSPENDED
MO0096679	BOD, 5-DAY (20 DEG. C)
MO0096679	COLIFORM, FECAL GENERAL
MO0096679	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0096679	PH
MO0096679	SOLIDS, TOTAL SUSPENDED
MO0097080	BOD, 5-DAY (20 DEG. C)
MO0097080	COLIFORM, FECAL GENERAL
MO0097080	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0097080	PH
MO0097080	SOLIDS, TOTAL SUSPENDED
MO0097446	BOD, 5-DAY (20 DEG. C)
MO0097446	COLIFORM, FECAL GENERAL
MO0097446	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0097446	PH
MO0097446	SOLIDS, TOTAL SUSPENDED
MO0097829	DATA NOT PROVIDED
MO0098272	BOD, 5-DAY (20 DEG. C)
MO0098272	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0098272	PH
MO0098272	SOLIDS, TOTAL SUSPENDED

NPID	Design criteria (parameter)
MO0098833	BOD, 5-DAY (20 DEG. C)
MO0098833	COLIFORM, FECAL GENERAL
MO0098833	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0098833	PH
MO0098833	SOLIDS, TOTAL SUSPENDED
MO0099155	BOD, 5-DAY (20 DEG. C)
MO0099155	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0099155	PH
MO0099155	SOLIDS, TOTAL SUSPENDED
MO0099309	BOD, 5-DAY (20 DEG. C)
MO0099309	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0099309	PH
MO0099309	SOLIDS, TOTAL SUSPENDED
MO0100251	BOD, 5-DAY (20 DEG. C)
MO0100251	COLIFORM, FECAL GENERAL
MO0100251	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0100251	PH
MO0100251	SOLIDS, TOTAL SUSPENDED
MO0100421	DATA NOT PROVIDED
MO0102253	AMMONIA, UNIONIZED
MO0102253	BOD, 5-DAY (20 DEG. C)
MO0102253	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0102253	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0102253	PH
MO0102253	SOLIDS, TOTAL SUSPENDED
MO0102253	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0103349	ARSENIC, TOTAL RECOVERABLE
MO0103349	BOD, 5-DAY(20 DEG. C)
MO0103349	CADMIUM TOTAL RECOVERABLE
MO0103349	CHROMIUM TOTAL RECOVERABLE
MO0103349	COPPER TOTAL RECOVERABLE
MO0103349	CYANIDE, FREE (AMEN.TO CHLORINATION)
MO0103349	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0103349	LEAD TOTAL RECOVERABLE
MO0103349	MERCURY TOTAL RECOVERABLE
MO0103349	NICKEL TOTAL RECOVERABLE
MO0103349	ORGANICS, TOTAL TOXIC (TTO)
MO0103349	PENTACHLOROPHENOL
MO0103349	PH
MO0103349	PHENOL, SINGLE COMPOUND
MO0103349	SOLIDS, TOTAL SUSPENDED
MO0103349	ZINC TOTAL RECOVERABLE
MO0104469	ACIDITY, TOTAL (AS CACO3)
MO0104469	ALKALINITY, TOTAL (AS CACO3)
MO0104469	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0104469	IRON, TOTAL (AS FE)
MO0104469	MANGANESE, TOTAL (AS MN)
MO0104469	PH
MO0104469	RAINFALL
MO0104469	SOLIDS, SETTLEABLE

NPID	Design criteria (parameter)
MO0104469	SOLIDS, TOTAL SUSPENDED
MO0104884	DATA NOT PROVIDED
MO0104906	ARSENIC, TOTAL (AS AS)
MO0104906	BOD, 5-DAY (20 DEG. C)
MO0104906	CADMIUM, TOTAL (AS CD)
MO0104906	CHROMIUM, TOTAL (AS CR)
MO0104906	COLIFORM, FECAL GENERAL
MO0104906	COPPER, TOTAL (AS CU)
MO0104906	CYANIDE,FREE (AMEN. TO CHLORINATION)
MO0104906	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0104906	IRON, TOTAL (AS FE)
MO0104906	LEAD, TOTAL (AS PB)
MO0104906	MERCURY, TOTAL (AS HG)
MO0104906	NICKEL, TOTAL (AS NI)
MO0104906	NITROGEN, AMMONIA TOTAL (AS N)
MO0104906	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0104906	ORGANICS, TOTAL TOXIC (TTO)
MO0104906	PH
MO0104906	PHENOL, SINGLE COMPOUND
MO0104906	SELENIUM, TOTAL (AS SE)
MO0104906	SOLIDS, TOTAL
MO0104906	SOLIDS, TOTAL SUSPENDED
MO0104906	SULFATE (AS S)
MO0104906	ZINC, TOTAL (AS ZN)
MO0105678	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0105678	PH
MO0105678	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0106135	BOD, 5-DAY (20 DEG. C)
MO0106135	COLIFORM, FECAL GENERAL
MO0106135	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0106135	PH
MO0106135	SOLIDS, TOTAL SUSPENDED
MO0106283	BOD, 5-DAY (20 DEG. C)
MO0106283	COLIFORM, FECAL GENERAL
MO0106283	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0106283	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0106283	PH
MO0106283	SOLIDS, TOTAL SUSPENDED
MO0106381	BOD, 5-DAY (20 DEG. C)
MO0106381	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0106381	PH
MO0106381	SOLIDS, TOTAL SUSPENDED
MO0106861	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0106861	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0106861	PH
MO0106861	SOLIDS, TOTAL SUSPENDED
MO0106861	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0107107	BOD, 5-DAY (20 DEG. C)
MO0107107	COLIFORM, FECAL GENERAL
MO0107107	FLOW, IN CONDUIT OR THRU TREATMENT PLANT

NPID	Design criteria (parameter)
MO0107107	PH
MO0107107	SOLIDS, TOTAL SUSPENDED
MO0107166	BOD, 5-DAY (20 DEG. C)
MO0107166	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0107166	NITRITE PLUS NITRATE TOTAL 1 DET. (AS N)
MO0107166	PH
MO0107166	PHOSPHORUS, TOTAL (AS P)
MO0107166	SOLIDS, TOTAL SUSPENDED
MO0107573	BOD, 5-DAY (20 DEG. C)
MO0107573	COLIFORM, FECAL GENERAL
MO0107573	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0107573	PH
MO0107573	SOLIDS, TOTAL SUSPENDED
MO0107581	BOD, 5-DAY(20 DEG. C)
MO0107581	COLIFORM, FECALGENERAL
MO0107581	FLOW, IN CONDUIT ORTHRU TREATMENT PLANT
MO0107581	PH
MO0107581	SOLIDS, TOTALSUSPENDED
MO0108677	DATA NOT PROVIDED
MO0108731	ARSENIC, TOTAL (AS AS)
MO0108731	BARIUM, TOTAL (AS BA)
MO0108731	BERYLLIUM, TOTAL (AS BE)
MO0108731	BOD, 5-DAY (20 DEG. C)
MO0108731	BORON, TOTAL (AS B)
MO0108731	CADMIUM, TOTAL (AS CD)
MO0108731	CALCIUM, TOTAL (AS CA)
MO0108731	CARBON, TOT ORGANIC (TOC)
MO0108731	CHLORIDES & SULFATES
MO0108731	CHROMIUM, TOTAL (AS CR)
MO0108731	COBALT, TOTAL (AS CO)
MO0108731	COPPER, TOTAL (AS CU)
MO0108731	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0108731	FLUORIDE, TOTAL (AS F)
MO0108731	HALOGENATED ORGANICS
MO0108731	IRON, TOTAL (AS FE)
MO0108731	LEAD, TOTAL (AS PB)
MO0108731	MAGNESIUM, TOTAL (AS MG)
MO0108731	MANGANESE, TOTAL (AS MN)
MO0108731	MERCURY, TOTAL (AS HG)
MO0108731	NICKEL, TOTAL (AS NI)
MO0108731	NITRITE PLUS NITRATE TOTAL 1 DET. (AS N)
MO0108731	NITROGEN, AMMONIA TOTAL (AS N)
MO0108731	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0108731	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0108731	PH
MO0108731	PHOSPHORUS, TOTAL (AS P)
MO0108731	SELENIUM, TOTAL (AS SE)
MO0108731	SILVER, TOTAL (AS AG)
MO0108731	SODIUM, TOTAL (AS NA)
MO0108731	SOLIDS, SETTLEABLE

NPID	Design criteria (parameter)
MO0108731	SOLIDS, TOTAL DISSOLVED
MO0108731	SOLIDS, TOTAL SUSPENDED
MO0108731	SPECIFIC CONDUCTANCE
MO0108731	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0108731	THALLIUM, TOTAL (AS TL)
MO0108731	ZINC, TOTAL (AS ZN)
MO0108766	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0108766	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0108766	PH
MO0108782	DATA NOT PROVIDED
MO0108871	BERYLLIUM, TOTAL (AS BE)
MO0108871	BOD, 5-DAY (20 DEG. C)
MO0108871	CADMIUM, TOTAL (AS CD)
MO0108871	CHLORIDES & SULFATES
MO0108871	CHROMIUM, TOTAL (AS CR)
MO0108871	COPPER, TOTAL (AS CU)
MO0108871	DATA NOT PROVIDED
MO0108871	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0108871	IRON, TOTAL (AS FE)
MO0108871	LEAD, TOTAL (AS PB)
MO0108871	MERCURY, TOTAL (AS HG)
MO0108871	NICKEL, TOTAL (AS NI)
MO0108871	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0108871	PH
MO0108871	SELENIUM, TOTAL (AS SE)
MO0108871	SILVER, TOTAL (AS AG)
MO0108871	SOLIDS, SETTLEABLE
MO0108871	SOLIDS, TOTAL DISSOLVED
MO0108871	SOLIDS, TOTAL SUSPENDED
MO0108871	SPECIFIC CONDUCTANCE
MO0108871	THALLIUM, TOTAL (AS TL)
MO0108871	ZINC, TOTAL (AS ZN)
MO0108952	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0108952	PH
MO0108952	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0109274	BOD, 5-DAY (20 DEG. C)
MO0109274	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0109274	PH
MO0109274	SOLIDS, TOTAL SUSPENDED
MO0109541	BOD, 5-DAY (20 DEG. C)
MO0109541	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0109541	NITROGEN, AMMONIA TOTAL (AS N)
MO0109541	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0109541	PH
MO0109541	SOLIDS, TOTAL SUSPENDED
MO0109541	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0110272	ARSENIC, TOTAL (AS AS)
MO0110272	BARIUM, TOTAL (AS BA)
MO0110272	BOD, 5-DAY (20 DEG. C)
MO0110272	BORON, TOTAL (AS B)

NPID	Design criteria (parameter)
MO0110272	CADMIUM, TOTAL (AS CD)
MO0110272	CALCIUM, TOTAL (AS CA)
MO0110272	CARBON, TOT ORGANIC (TOC)
MO0110272	CHLORIDES & SULFATES
MO0110272	CHROMIUM, TOTAL (AS CR)
MO0110272	COBALT, TOTAL (AS CO)
MO0110272	COPPER, DISSOLVED (AS CU)
MO0110272	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0110272	FLUORIDE, TOTAL (AS F)
MO0110272	HALOGENATED ORGANICS
MO0110272	HARDNESS, TOT CALC. (CA,MG,FE) AS CAC03
MO0110272	IRON, DISSOLVED (AS FE)
MO0110272	LEAD, TOTAL (AS PB)
MO0110272	MAGNESIUM, TOTAL (AS MG)
MO0110272	MANGANESE, TOTAL (AS MN)
MO0110272	MERCURY, TOTAL (AS HG)
MO0110272	NICKEL, TOTAL (AS NI)
MO0110272	NITRITE PLUS NITRATE TOTAL 1 DET. (AS N)
MO0110272	NITROGEN, AMMONIA TOTAL (AS N)
MO0110272	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0110272	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0110272	PH
MO0110272	PHENOL, SINGLE COMPOUND
MO0110272	PHOSPHORUS, TOTAL (AS P)
MO0110272	SELENIUM, TOTAL (AS SE)
MO0110272	SILVER, TOTAL (AS AG)
MO0110272	SODIUM, TOTAL (AS NA)
MO0110272	SOLIDS, SETTLEABLE
MO0110272	SPECIFIC CONDUCTANCE
MO0110272	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0110272	ZINC, TOTAL (AS ZN)
MO0110299	DATA NOT PROVIDED
MO0110426	ARSENIC, TOTAL (AS AS)
MO0110426	BARIUM, TOTAL (AS BA)
MO0110426	BOD, 5-DAY (20 DEG. C)
MO0110426	BORON, TOTAL (AS B)
MO0110426	CADMIUM, TOTAL (AS CD)
MO0110426	CALCIUM, TOTAL (AS CA)
MO0110426	CARBON, TOT ORGANIC (TOC)
MO0110426	CHLORIDES & SULFATES
MO0110426	CHROMIUM, TOTAL (AS CR)
MO0110426	COBALT, TOTAL (AS CO)
MO0110426	COPPER, TOTAL (AS CU)
MO0110426	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0110426	FLUORIDE, TOTAL (AS F)
MO0110426	HALOGENS, TOT ORGAN-ICS BOTTOM SEDIMENT
MO0110426	HARDNESS, TOTAL (AS CACO3)
MO0110426	IRON, TOTAL (AS FE)
MO0110426	LEAD, TOTAL (AS PB)
MO0110426	MAGNESIUM, TOTAL (AS MG)

NPID	Design criteria (parameter)
MO0110426	MANGANESE, TOTAL (AS MN)
MO0110426	MERCURY, TOTAL (AS HG)
MO0110426	NICKEL, TOTAL (AS NI)
MO0110426	NITRITE PLUS NITRATE TOTAL 1 DET. (AS N)
MO0110426	NITROGEN, AMMONIA TOTAL (AS N)
MO0110426	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0110426	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0110426	PH
MO0110426	PHENOL, SINGLE COMPOUND
MO0110426	PHOSPHORUS, TOTAL (AS P)
MO0110426	SELENIUM, TOTAL (AS SE)
MO0110426	SILVER, TOTAL (AS AG)
MO0110426	SODIUM, TOTAL (AS NA)
MO0110426	SOLIDS, SETTLEABLE
MO0110426	SOLIDS, TOTAL DISSOLVED- 180 DEG.C
MO0110426	SPECIFIC CONDUCTANCE
MO0110426	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0110426	ZINC, TOTAL (AS ZN)
MO0111023	DATA NOT PROVIDED
MO0111309	CARBON, TOT ORGANIC (TOC)
MO0111309	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0111309	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0111309	PH
MO0111317	CARBON, TOT ORGANIC (TOC)
MO0111317	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0111317	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0111317	PH
MO0111325	ACENAPHTHENE
MO0111325	ANTHRACENE
MO0111325	ARSENIC, DISSOLVED (AS AS)
MO0111325	ARSENIC, TOTAL (AS AS)
MO0111325	BENZO(A)ANTHRACENE
MO0111325	BENZO(A)PYRENE
MO0111325	BENZO(GHI)PERYLENE
MO0111325	BENZO(K)FLUORANTHENE
MO0111325	BOD, 5-DAY (20 DEG. C)
MO0111325	CHLORIDE
MO0111325	CHLORINATED DIBENZO-FURANS, EFFLUENT
MO0111325	CHLORINATED DIBENZO-P-DIOXINS, EFFLUENT
MO0111325	CHROMIUM, HEXAVALENT (AS CR)
MO0111325	CHROMIUM, HEXAVALENT DISSOLVED (AS CR)
MO0111325	CHROMIUM, TRIVALENT (AS CR)
MO0111325	CHRYSENE
MO0111325	COPPER, DISSOLVED (AS CU)
MO0111325	COPPER, TOTAL (AS CU)
MO0111325	DIBENZO (A,H) ANTHRACENE
MO0111325	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0111325	FLUORANTHENE
MO0111325	FLUORENE
MO0111325	INDENO (1,2,3-CD) PYRENE

NPID	Design criteria (parameter)
MO0111325	NAPHTHALENE
MO0111325	NITRITE PLUS NITRATE TOTAL 1 DET. (AS N)
MO0111325	NITROGEN, AMMONIA TOTAL (AS N)
MO0111325	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0111325	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0111325	PENTACHLOROPHENOL
MO0111325	PH
MO0111325	PHENANTHRENE
MO0111325	PHENOL, SINGLE COMPOUND
MO0111325	PYRENE
MO0111325	SOLIDS, TOTAL SUSPENDED
MO0111325	SULFATE (AS S)
MO0111325	TEMPERATURE, WATER DEG. FAHRENHEIT
MO0111325	ZINC, DISSOLVED (AS ZN)
MO0111325	ZINC, TOTAL (AS ZN)
MO0111741	ARSENIC, TOTAL RECOVERABLE
MO0111741	BARIUM, TOTAL RECOVERABLE
MO0111741	BOD, 5-DAY (20 DEG. C)
MO0111741	BORON, TOTAL RECOVERABLE
MO0111741	CADMIUM TOTAL RECOVERABLE
MO0111741	CALCIUM, TOTAL (AS CA)
MO0111741	CHLORIDES & SULFATES
MO0111741	CHROMIUM TOTAL RECOVERABLE
MO0111741	COBALT, TOTAL RECOVERABLE
MO0111741	COPPER TOTAL RECOVERABLE
MO0111741	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0111741	FLUORIDE, TOTAL (AS F)
MO0111741	HARDNESS, TOTAL (AS CACO3)
MO0111741	IRON, TOTAL (AS FE)
MO0111741	LEAD TOTAL RECOVERABLE
MO0111741	MAGNESIUM, TOTAL RECOVERABLE
MO0111741	MANGANESE, TOTAL RECOVERABLE
MO0111741	MERCURY TOTAL RECOVERABLE
MO0111741	NITRITE PLUS NITRATE TOTAL 1 DET. (AS N)
MO0111741	NITROGEN, AMMONIA TOTAL (AS N)
MO0111741	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0111741	PH
MO0111741	PHOSPHORUS, TOTAL (AS P)
MO0111741	RAINFALL
MO0111741	SELENIUM, TOTAL RECOVERABLE
MO0111741	SILVER TOTAL RECOVERABLE
MO0111741	SODIUM, TOTAL (AS NA)
MO0111741	SOLIDS, SETTLEABLE
MO0111741	SOLIDS, TOTAL DISSOLVED- 180 DEG.C
MO0111741	SOLIDS, TOTAL SUSPENDED
MO0111741	SPECIFIC CONDUCTANCE
MO0111741	ZINC TOTAL RECOVERABLE
MO0111791	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0111791	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0111791	PH

NPID	Design criteria (parameter)
MO0111791	SOLIDS, TOTAL SUSPENDED
MO0112046	ARSENIC, TOTAL (AS AS)
MO0112046	BARIUM, TOTAL (AS BA)
MO0112046	BOD, 5-DAY (20 DEG. C)
MO0112046	BORON, TOTAL (AS B)
MO0112046	CADMIUM, TOTAL (AS CD)
MO0112046	CALCIUM, TOTAL (AS CA)
MO0112046	CHLORIDES & SULFATES
MO0112046	CHROMIUM, TOTAL (AS CR)
MO0112046	COBALT, TOTAL (AS CO)
MO0112046	COPPER, TOTAL (AS CU)
MO0112046	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0112046	FLUORIDE, TOTAL (AS F)
MO0112046	FORMALDEHYDE
MO0112046	HARDNESS, TOTAL (AS CACO3)
MO0112046	IRON, TOTAL (AS FE)
MO0112046	LEAD, TOTAL (AS PB)
MO0112046	MAGNESIUM, TOTAL (AS MG)
MO0112046	MANGANESE, TOTAL (AS MN)
MO0112046	MERCURY, TOTAL (AS HG)
MO0112046	NITRITE PLUS NITRATE TOTAL 1 DET. (AS N)
MO0112046	NITROGEN, AMMONIA TOTAL (AS N)
MO0112046	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0112046	PH
MO0112046	PHOSPHORUS, TOTAL (AS P)
MO0112046	SELENIUM, TOTAL (AS SE)
MO0112046	SILVER, TOTAL (AS AG)
MO0112046	SODIUM, TOTAL (AS NA)
MO0112046	SOLIDS, SETTLEABLE
MO0112046	SOLIDS, TOTAL DISSOLVED- 180 DEG.C
MO0112046	SOLIDS, TOTAL SUSPENDED
MO0112046	SPECIFIC CONDUCTANCE
MO0112046	ZINC, TOTAL (AS ZN)
MO0112101	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0112101	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0112101	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0112101	PH
MO0112101	RAINFALL
MO0112101	SOLIDS, TOTAL SUSPENDED
MO0112119	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0112119	OIL AND GREASE (SOXHLET EXTR.) TOT.
MO0112119	OXYGEN DEMAND, CHEM. (HIGH LEVEL) (COD)
MO0112119	PH
MO0112119	RAINFALL
MO0112119	SOLIDS, TOTAL SUSPENDED
MO0112372	DATA NOT PROVIDED
MO0112534	BOD, 5-DAY(20 DEG. C)
MO0112534	COLIFORM, FECAL GENERAL
MO0112534	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
MO0112534	PH

NPID	Design criteria (parameter)
MO0112534	SOLIDS, TOTALSUSPENDED
MO0112631	DATA NOT PROVIDED
OK0001040	FLOW RATE
OK0001040	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0001040	OIL AND GREASE (SOXHLET EXTR.) TOT.
OK0001040	OIL AND GREASE FREON EXTR-GRAV METH
OK0001040	PH
OK0001040	SOLIDS, TOTAL SUSPENDED
OK0001261	BIOASSAY (24 HR.)
OK0001261	CHLORINE, TOTAL RESIDUAL
OK0001261	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0001261	HLF P/F STATRE 7DAY CHR CERIODAPHNIA
OK0001261	HLF P/F STATRE 7DAY CHR PIMEPHALES
OK0001261	LF P/F STATRE 7DAY CHR PIMEPHALES
OK0001261	LF P/F STATRE 7DAY CHR CERIODAPHNIA
OK0001261	PH
OK0001261	SOLIDS, TOTAL DISSOLVED
OK0001261	SOLIDS, TOTAL SUSPENDED
OK0020320	BOD, 5-DAY (20 DEG. C)
OK0020320	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0020320	PH
OK0020320	SOLIDS, TOTAL SUSPENDED
OK0020656	BOD, 5-DAY (20 DEG. C)
OK0020656	CHLORINE, TOTAL RESIDUAL
OK0020656	COLIFORM, FECAL GENERAL
OK0020656	COLIFORM, TOTAL GENERAL
OK0020656	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0020656	PH
OK0020656	SOLIDS, TOTAL SUSPENDED
OK0021172	BOD, 5-DAY (20 DEG. C)
OK0021172	COLIFORM, FECAL GENERAL
OK0021172	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0021172	PH
OK0021172	SOLIDS, TOTAL SUSPENDED
OK0021458	BOD, 5-DAY (20 DEG. C)
OK0021458	COLIFORM, FECAL GENERAL
OK0021458	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0021458	PH
OK0021458	SOLIDS, TOTAL SUSPENDED
OK0021504	BOD, 5-DAY (20 DEG. C)
OK0021504	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0021504	PH
OK0021504	SOLIDS, TOTAL SUSPENDED
OK0028258	BOD, 5-DAY (20 DEG. C)
OK0028258	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0028258	PH
OK0028258	SOLIDS, TOTAL SUSPENDED
OK0028291	BOD, 5-DAY (20 DEG. C)
OK0028291	COLIFORM, FECAL GENERAL
OK0028291	FLOW, IN CONDUIT OR THRU TREATMENT PLANT

NPID	Design criteria (parameter)
OK0028291	PH
OK0028291	SOLIDS, TOTAL SUSPENDED
OK0028886	BOD, 5-DAY (20 DEG. C)
OK0028886	CHLORINE, TOTAL RESIDUAL
OK0028886	COLIFORM, FECAL GENERAL
OK0028886	COLIFORM, TOTAL GENERAL
OK0028886	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0028886	PH
OK0028886	SOLIDS, TOTAL SUSPENDED
OK0030236	BOD, 5-DAY (20 DEG. C)
OK0030236	COLIFORM, FECAL GENERAL
OK0030236	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0030236	NITROGEN, AMMONIA TOTAL (AS N)
OK0030236	OXYGEN, DISSOLVED (DO)
OK0030236	PH
OK0030236	SOLIDS, TOTAL SUSPENDED
OK0031798	BOD, 5-DAY (20 DEG. C)
OK0031798	CHLORINE, TOTAL RESIDUAL
OK0031798	COLIFORM, FECAL GENERAL
OK0031798	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0031798	PH
OK0031798	SOLIDS, TOTAL SUSPENDED
OK0031801	BOD, 5-DAY (20 DEG. C)
OK0031801	CADMIUM, TOTAL (AS CD)
OK0031801	CHLORINE, TOTAL RESIDUAL
OK0031801	COLIFORM, FECAL GENERAL
OK0031801	COLIFORM, TOTAL GENERAL
OK0031801	COPPER, TOTAL (AS CU)
OK0031801	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0031801	HLF P/F STATRE 7DAY CHR CERIODAPHNIA
OK0031801	HLF P/F STATRE 7DAY CHR PIMEPHALES
OK0031801	LF P/F STATRE 7DAY CHR PIMEPHALES
OK0031801	LF P/F STATRE 7DAY CHR CERIODAPHNIA
OK0031801	PH
OK0031801	SOLIDS, TOTAL SUSPENDED
OK0031976	BOD, 5-DAY (20 DEG. C)
OK0031976	CHLORINE, TOTAL RESIDUAL
OK0031976	COLIFORM, FECAL GENERAL
OK0031976	COLIFORM, TOTAL GENERAL
OK0031976	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0031976	PH
OK0031976	SOLIDS, TOTAL SUSPENDED
OK0032263	BOD, 5-DAY (20 DEG. C)
OK0032263	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0032263	PH
OK0032263	SOLIDS, TOTAL SUSPENDED
OK0034789	BOD, 5-DAY (20 DEG. C)
OK0034789	CHLORINE, TOTAL RESIDUAL
OK0034789	COLIFORM, FECAL GENERAL
OK0034789	COLIFORM, TOTAL GENERAL

NPID	Design criteria (parameter)
OK0034789	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0034789	PH
OK0034789	SOLIDS, TOTAL SUSPENDED
OK0034835	BOD, 5-DAY (20 DEG. C)
OK0034835	CHLORINE, TOTAL RESIDUAL
OK0034835	COLIFORM, FECAL GENERAL
OK0034835	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0034835	PH
OK0034835	SOLIDS, TOTAL SUSPENDED
OK0037036	BOD, 5-DAY (20 DEG. C)
OK0037036	COLIFORM, FECAL GENERAL
OK0037036	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0037036	PH
OK0037036	SOLIDS, TOTAL SUSPENDED
OK0037770	BOD, 5-DAY (20 DEG. C)
OK0037770	COLIFORM, FECAL GENERAL
OK0037770	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0037770	PH
OK0037770	SOLIDS, TOTAL SUSPENDED
OK0037842	BOD, 5-DAY (20 DEG. C)
OK0037842	COLIFORM, FECAL GENERAL
OK0037842	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0037842	PH
OK0037842	SOLIDS, TOTAL SUSPENDED
OK0037869	BOD, 5-DAY (20 DEG. C)
OK0037869	CHLORINE, TOTAL RESIDUAL
OK0037869	COLIFORM, FECAL GENERAL
OK0037869	COLIFORM, TOTAL GENERAL
OK0037869	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0037869	PH
OK0037869	SOLIDS, TOTAL SUSPENDED
OK0037915	BOD, 5-DAY (20 DEG. C)
OK0037915	COLIFORM, FECAL GENERAL
OK0037915	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0037915	PH
OK0037915	SOLIDS, TOTAL SUSPENDED
OK0037923	BOD, 5-DAY (20 DEG. C)
OK0037923	COLIFORM, FECAL GENERAL
OK0037923	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0037923	PH
OK0037923	SOLIDS, TOTAL SUSPENDED
OK0037991	BOD, 5-DAY (20 DEG. C)
OK0037991	COLIFORM, FECAL GENERAL
OK0037991	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0037991	PH
OK0037991	SOLIDS, TOTAL SUSPENDED
OK0038041	BOD, 5-DAY (20 DEG. C)
OK0038041	COLIFORM, FECAL GENERAL
OK0038041	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0038041	PH

NPID	Design criteria (parameter)
OK0038041	SOLIDS, TOTAL SUSPENDED
OK0038598	DATA NOT PROVIDED
OK0038687	DATA NOT PROVIDED
OK0038962	BOD, 5-DAY (20 DEG. C)
OK0038962	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0038962	PH
OK0038962	SOLIDS, TOTAL SUSPENDED
OK0039039	BOD, 5-DAY (20 DEG. C)
OK0039039	CHLORINE, TOTAL RESIDUAL
OK0039039	COLIFORM, FECAL GENERAL
OK0039039	COLIFORM, TOTAL GENERAL
OK0039039	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0039039	PH
OK0039039	SOLIDS, TOTAL SUSPENDED
OK0039098	BOD, 5-DAY (20 DEG. C)
OK0039098	CHLORINE, TOTAL RESIDUAL
OK0039098	COLIFORM, FECAL GENERAL
OK0039098	COLIFORM, TOTAL GENERAL
OK0039098	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0039098	PH
OK0039098	SOLIDS, TOTAL SUSPENDED
OK0039144	BOD, 5-DAY (20 DEG. C)
OK0039144	CHLORINE, TOTAL RESIDUAL
OK0039144	COLIFORM, FECAL GENERAL
OK0039144	COLIFORM, TOTAL GENERAL
OK0039144	FLOW, IN CONDUIT OR THRU TREATMENT PLANT
OK0039144	PH
OK0039144	SOLIDS, TOTAL SUSPENDED
OK0040142	DATA NOT PROVIDED
OK0041009	DATA NOT PROVIDED
OK0041025	DATA NOT PROVIDED